Net op Zee – Nederwiek 2

Aanvraag watervergunning Rijkswaterstaat

Bijlage 16: Inventariserend archeologisch veldonderzoek

Net op zee Nederwiek 2

An archaeological assessment
Of geophysical and geotechnical survey results

Authors

[redacted]

At the request of

Arcadis Nederland BV

On behalf of

TenneT TSO BV

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Net op Zee Nederwiek 2 – An archaeological assessment of geophysical & geotechnical survey results
Authors: R. van Lil and R.W. Cassée

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Periplus Archeomare

Periplus Archeomare BV
Kraanspoor 14
1033 SE – Amsterdam
Tel: 020-6367891
Email: info@periplus.nl
Website: www.periplus.nl

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Table 1. Dutch archaeological periods

Period	Time in Years				
Post-medieval / Modern Times	1500	A.D.	-	Present	
Late medieval period	1050	A.D.	-	1500	A.D.
Early medieval period	450	A.D.	-	1050	A.D.
Roman Times	12	B.C.	-	450	A.D.
Iron Age	800	B.C.	-	12	B.C.
Bronze Age	2000	B.C.	-	800	B.C.
Neolithic (New Stone Age)	5300	B.C.	-	2000	B.C.
Mesolithic (Stone Age)	8800	B.C.	-	4900	B.C.
Palaeolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Table 2. Administrative details

Location:	North Sea, Noord-Beveland, Veere en Middelburg	
Toponym Dutch:	Net op Zee Nederwiek 2	
Chart:	1801-01, 42W & 48W	
Coordinates Geodetic datum: ETRS89 Projection: UTM31N	Centre	E 436 144 - N 5 813 599
	NW	E 514 162 – N 5 909 712
	NE	E 567 805 – N 5 909 712
	SW	E 514 162 – N 5 707 570
	SE	E 567 805 – N 5 707 570
Depth (LAT):	0 to 42.8 meters, average of 26.1 meters	
Area surveyed	488.8 km^2	
Environment:	Tidal currents, saltwater	
Area use:	Shipping, fishing; oil and gas industry	
Area administrator:	Rijkswaterstaat Zee en Delta	
Competent authority	Rijkswaterstaat Zee en Delta	
Advising body	Dutch Cultural Heritage Agency	
ARCHIS-research report (CIS-code):	5387646100	
Periplus-project reference:	22A028-02	
Period	March – May 2023	

Samenvatting (Abstract in Dutch)

Arcadis Nederland BV heeft namens Tennet TSO BV Periplus Archeomare BV opdracht verleend om de resultaten van de geofysische en geotechnische surveys van de exportkabel Net op Zee Nederwiek 2 archeologisch te beoordelen.

De eerste stap in het proces van archeologisch onderzoek (= AMZ-cyclus) is het bureauonderzoek. Het bureauonderzoek heeft uitgewezen dat in het onderzoeksgebied overblijfselen van scheepswrakken, resten van gevechtsvliegtuigen uit WOII en prehistorische landschappen en daaraan gerelateerde archeologische resten verwacht kunnen worden.

De tweede stap in de AMZ-cyclus is de analyse en beoordeling van geofysische survey data. Het doel van deze beoordeling is de archeologische verwachting van het bureauonderzoek te toetsen. Voor deze toets zijn in het 489 km^2 omvattende onderzoeksgebied side scan sonar, magnetometer, multibeam echo sounder en subbottom profiler data geanalyseerd.

Binnen het onderzochte gebied is aan 53 sonarcontacten een archeologische verwachting toegekend.

Langs de Nederwiek 2-route vallen 2 van de sonarcontacten binnen 100 meter van de route (zie tabel '*Exposed contacts (side scan sonar) of potential archaeological value within 100 meters from* Nederwiek 2 *route*' in de Engelstalige samenvatting). Aan deze sonarcontacten is een archeologische verwachting toegekend totdat het tegendeel bewezen is na aanvullend onderzoek door een gecertificeerde archeoloog.

Magnetische anomalieën

Op 87 locaties zijn magnetische anomalieën met een piek-tot-piekwaarde van meer dan 500 nT in kaart gebracht. Deze anomalieën kunnen correleren niet met bekende objecten zoals pijpleidingen of kabels. De anomalieën kunnen verband houden met ijzerhoudende objecten die van mogelijk archeologisch belang zijn. De objecten die deze anomalieën veroorzaken zijn niet zichtbaar op side scan sonar- of multibeambeelden en worden daarom als afgedekt in de zeebodem beschouwd. De aard van deze objecten is niet bekend. Naast archeologische objecten kunnen de anomalieën daarom ook door niet-archeologische objecten zoals niet-ontplofte explosieven, ankers en verloren of gedumpt materiaal veroorzaakt zijn. Zolang de aard van deze objecten niet is bepaald, worden de objecten als potentieel archeologisch waardevol beschouwd.

Langs de Nederwiek 2-route vallen 9 van de magnetometercontacten binnen 100 meter van de route (zie tabel 'Buried contacts (magnetometer) of potential archaeological value within 100 meters from Nederwiek 2-route' in de Engelstalige samenvatting).

Volgens de richtlijnen van de Rijksdienst voor het Cultureel Erfgoed (RCE) mogen geen verstoringen van de zeebodem plaatsvinden binnen 100 meter van elk van de gemarkeerde locaties. De bufferzone van 100 meter is een standaard die van toepassing is op, en dient ter de bescherming van het cultureel erfgoed. Rijkswaterstaat is de handhavende autoriteit namens het ministerie van Economische Zaken en Klimaat.

De 100 m bufferzone kan worden verkleind als kan worden onderbouwd dat de toegepaste verstoring geen invloed heeft op het archeologische object; bijvoorbeeld wanneer tijdens kabellegoperaties geen ankers worden gebruikt. Verkleining van de afstand moet worden goedgekeurd door Rijkswaterstaat (RWS). De Rijksdienst voor het Cultureel Erfgoed (RCE) treedt hierbij op als adviseur van Rijkswaterstaat. Als er activiteiten plaatsvinden binnen 100 meter van een potentiële archeologische locatie, zal in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) per geval bekeken moeten worden of deze 100 meter afstand gehandhaafd moet worden.

Alle locaties van potentieel archeologisch belang worden weergegeven de afbeelding '*Locations of potential archaeological interest including Areas to be avoided.*' in de Engelstalige samenvatting. Alle locaties van potentieel archeologisch belang, inclusief een bufferzone van 100 m, worden in deze afbeelding weergegeven.

Als het niet haalbaar is om de gemelde magnetometer anomalieën te vermijden, is aanvullend onderzoek nodig om de archeologische waarde van de objecten die de anomalieën veroorzaken te bepalen.

Als vervolg op het huidige geofysische onderzoek wordt aanvullend gedetailleerd onderzoek naar UXO's uitgevoerd. De resultaten ter plaatse van de potentieel archeologische locaties te dienen archeologisch te worden beoordeeld. Indien uit de beoordeling blijkt dat een object/objecten niet van archeologische waarde is/zijn, kan de betreffende locatie worden vrijgegeven. De resultaten van dit onderzoek moeten als bijlage aan het onderhavig rapport worden toegevoegd.

Prehistorische landschappen en gerelateerde archeologische resten
Het onderzoek van seismische gegevens, vibrocore-beschrijvingen en CPT-logs heeft aangetoond dat een intacte, goed bewaarde sequentie van laat-Pleistocene en vroeg-Holocene landschappen lokaal langs de kabelroute bewaard kan zijn gebleven. Het is niet mogelijk om specifieke plekken aan te wijzen waar het Pleistocene landschap intact is. Daarom kan niet worden uitgesloten dat in een deel van het traject intacte, goed bewaarde prehistorische landschappen en daaraan gerelateerde archeologische resten worden aangetast door de installatie van de kabels. Vanwege de kleine omvang van laat-paleolithische en mesolithische kampplaatsen is het erg moeilijk om deze locaties op te sporen en in kaart te brengen. Maatregelen om verstoring van deze kampplaatsen te voorkomen vormen daarom geen optie.

De analyse van vibrocore-monsters biedt de mogelijkheid om belangrijke informatie te verkrijgen over de ontwikkeling van late-Pleistocene en vroeg-Holocene terrestrische en aquatische landschappen die worden doorkruist door de kabels. Geadviseerd wordt om specialistisch onderzoek uit te voeren. Dit onderzoek bestaat uit AMS 14C en/of OSL-dateringen, en de analyse van palynomorfen en microfossielen. De selectie van vibrocores en monsterintervallen moet, in overeenstemming met de Kwaliteitsnorm Nederlandse Archeologie, worden opgenomen in een Plan van Aanpak. Voorgesteld wordt om vooral te richten op bemonstering met een groot interval op een beperkt aantal representatieve vibrocores.

Summary

Arcadis Nederland BV on behalf of TenneT TSO BV has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical and geotechnical survey results of the export cable route Net op Zee Nederwiek 2.

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echo sounder* and *subbottom profiling*) recorded within the survey corridor covering a total area of 489 km^2 have been analysed in order to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Within the surveyed area, an archaeological expectation was assigned to a total of 53 contacts. In accordance with the directive from the Cultural Heritage Agency of the Netherlands (RCE), no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). These side scan sonar contacts are considered to be of archaeological value until it is proven not to be through an additional assessment done by a certified archaeologist.

Along the Nederwiek 2 route, 2 of the sonar contacts fall within 100 meters of the route.

ID	E	N	Distance to the cable(m)
SSS_GVA_01403	536762	5807461	64
SSS_COB_02273	525796	5907245	37

Table 3. Potential archaeological contacts within 100 meters from route Nederwiek 2

Magnetic anomalies

At 87 locations magnetic anomalies with a peak-to-peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Along the Nederwiek 2 route, 9 of the magnetometer contacts fall within 100 meters of the route.

Anom_ID	Amplitude	Easting	Northing	Distance to the cable(m)
MAG_BEA_0066	919.2	567692	5752519	50
MAG_BEA_0082	1238.4	567622	5752445	75
MAG_LOC_410012	612.6	555549	5751212	66
MAG_COB_00535	559.5	536761	5803815	3
MAG_COB_00488	560.9	536831	5803830	74
MAG_COB_01114	3511.3	516294	5860969	1
MAG_BRK_60678	2669.7	515268	5866394	3
MAG_BRK_60946	2471.6	523727	5898339	5
MAG_COB_02590	571.1	523781	5898359	62

Table 4. Potential archaeological magnetometer contacts within 100 meters from route Nederwiek 2

In accordance with the directive from the Cultural Heritage Agency of the Netherlands (RCE), no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the RCE. The listed magnetometer contacts are considered to be of archaeological value until proven otherwise through an additional assessment by a certified archaeologist. All locations of potential archaeological interest are shown in figure 1.

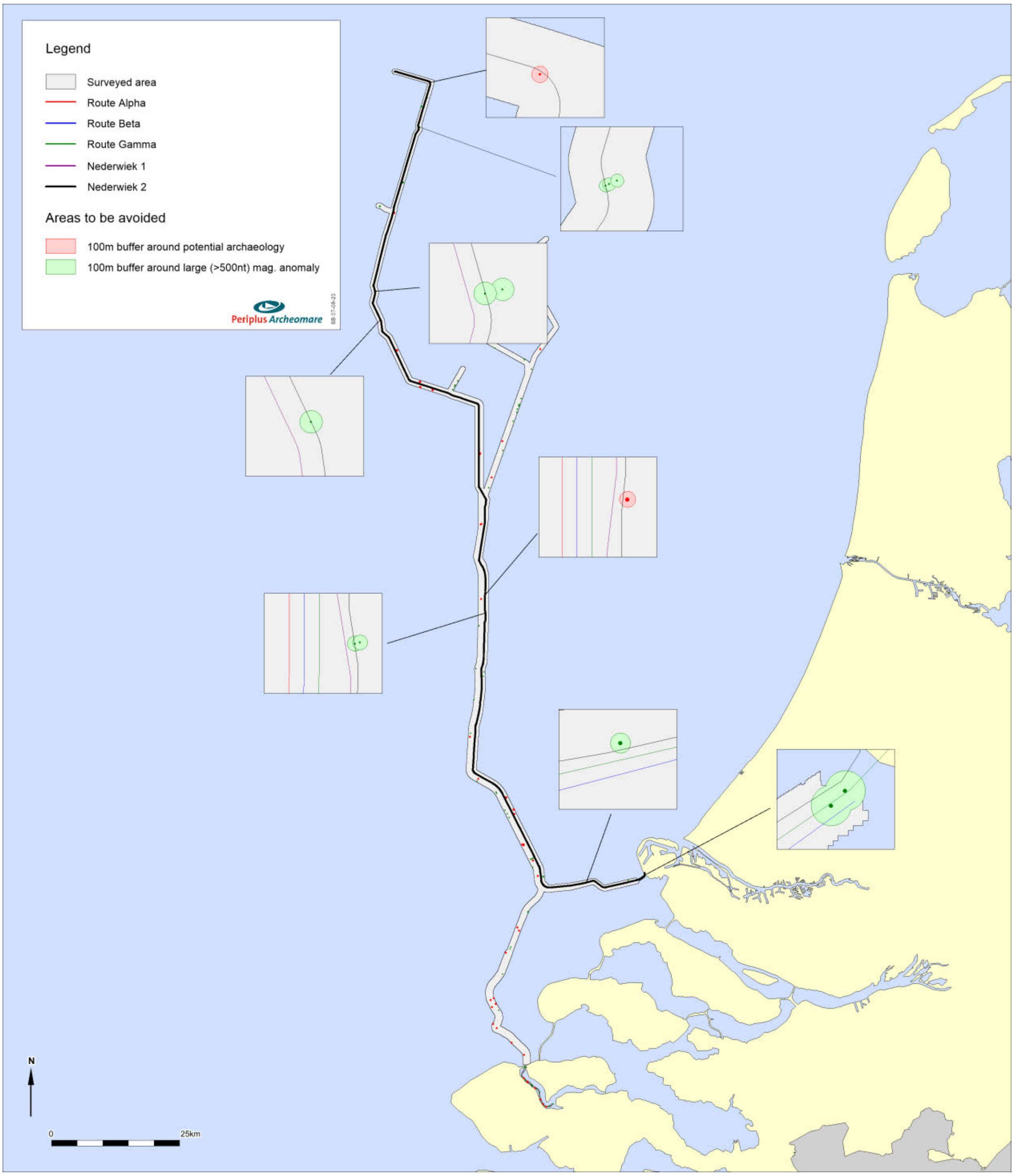

Figure 1. Advice - Sites to be avoided along the Nederwiek 2 route including a 100-meter buffer zone.

The buffer zone of 100 meters is a standard that applies to the protection of cultural heritage. However, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. The reduction of the distance has to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the enforcing authority, acting on behalf of the Ministry of Economic Affairs and Climate Policy. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported *magnetometer* locations, additional research is required in order to determine the actual archaeological value of the reported locations. It is advised that the UXO research within 100 meters of the *magnetometer* anomalies are carried out under archaeological supervision. Depending on the outcome of the UXO research it can be decided if additional archaeological investigation (for instance through ROV or dive investigations) is needed. If the UXO research indicates that the object has no archaeological value, the location can be omitted. The results of the UXO research will be published in an addendum.

Prehistoric landscapes and related archaeological remains

The assessment of seismic data, vibrocore descriptions and CPT-logs has shown that an intact well-preserved sequence of Late Pleistocene and Early Holocene landscapes could locally have been preserved along the cable route. It is not possible to specifically target the areas where the Pleistocene landscape is intact. Therefore, it cannot be excluded that in part of the trajectory intact well-preserved prehistoric landscapes and possible archaeological remains contained herein are affected by the installation of the cables. However, due to the small size of Late Paleolithic and Mesolithic campsites it is exceedingly difficult to trace and map these sites. Generally, these campsites do not exceed a few m^2. Therefore, it is not possible to take mitigating measures to prevent disturbance of sites.

The analysis of vibrocore samples offers an opportunity to gain valuable information on the development of Late Pleistocene and Early Holocene terrestrial and aquatic landscapes which are crossed by the cables. It is advised to conduct specialist research including AMS ^{14}C age dating, pollen, diatom, foraminifera, and ostracod analysis. The designation of vibrocores and sample intervals shall, in accordance with the Dutch Quality Standard (Dutch: Kwaliteitsnorm Nederlandse Archeologie) be documented in a Plan of Action. It is suggested to focus on a limited number of representative vibrocores, from which a large number of intervals are sampled, instead of selecting a large number of vibrocores from which a small number of samples are taken.

During the installation of the cables, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend archaeological supervision based on an approved Program of Requirements. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Rijkswaterstaat). This notification must also be included in the scope of work.

1 Introduction

Arcadis Nederland BV on behalf of TenneT TSO BV has contracted Periplus Archeomare BV to conduct an archaeological assessment of geophysical and geotechnical survey results of the export cable route Net op Zee Nederwiek 2.

The surveyed area, covering 167 km^2, is located in the North Sea, north of Zeeland. The results of the assessment are supplemented with the geophysical and geotechnical survey results of the export cables route to the IJmuiden Ver Wind Farm Zone, so that the total research area amounts to 489 km^2.

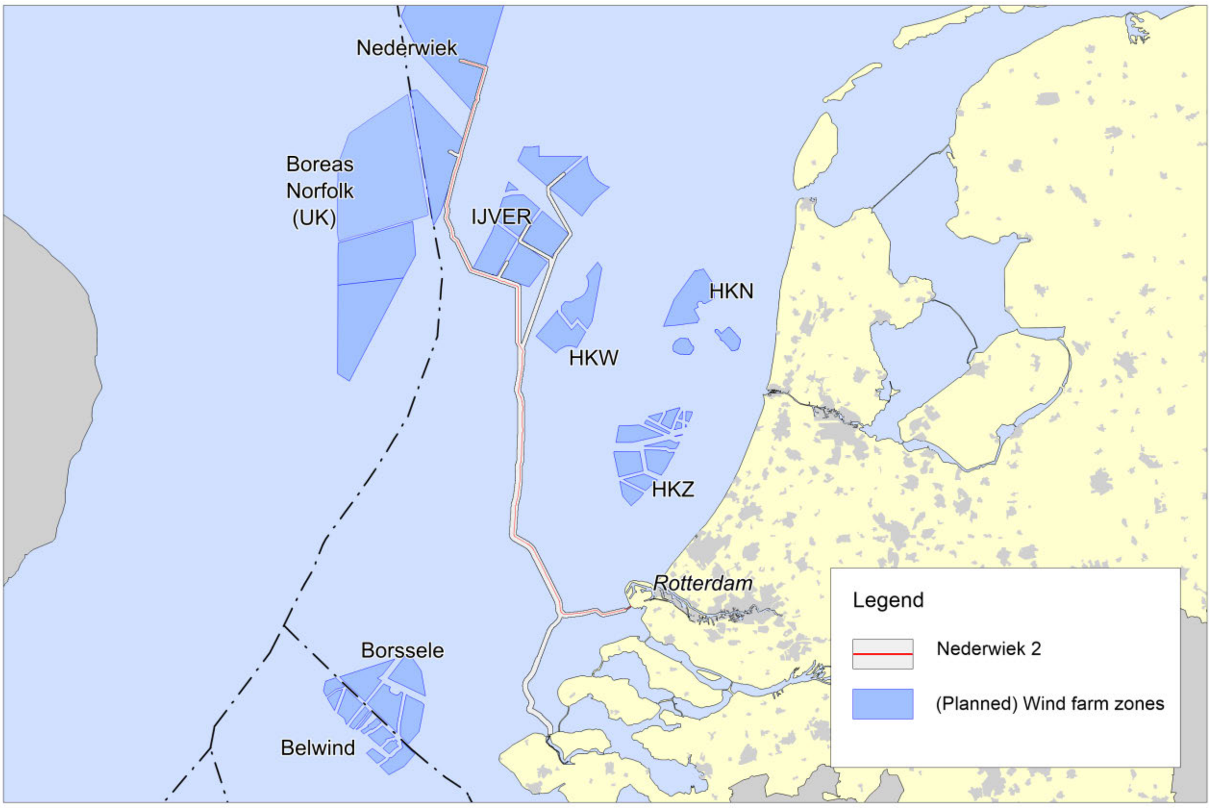

Figure 2. Location map of area of investigation

1.1 Background

The Netherlands has formulated ambitious objectives for reducing CO2 emissions, and related to that, producing sustainable energy. Offshore wind energy plays a prominent role in this policy, as laid out in the 2019 Climate Agreement. The North Sea is a favourable place for offshore wind energy because of the relatively shallow water depth and the favourable wind climate. Furthermore, there are good ports and (industrial) energy consumers nearby.

In 2019 offshore wind farms with a total capacity of approximately 1 gigawatt (GW) were operational in the Dutch part of the North Sea. In line with the Energy Agreement for Sustainable Growth (2013) in the years 2020-2023 approximately every year an offshore wind farm of 0.7 GW will be built in the Wind Farm Zones Borssele, Hollandse Kust (zuid) and Hollandse Kust (noord).

From 2024 to 2030, further out to sea offshore wind farms will follow to the west and north in (parts of) the Wind Farm Zones Hollandse Kust (west), Ten noorden van de Waddeneilanden, IJmuiden Ver, and Nederwiek. In 2030 a total capacity of approximately 11 GW of offshore wind farms will be realized with a target production of 49 TWh as defined in the Climate Agreement. The wind farms then supply 8.5% of all energy in the Netherlands and 40% of our current electricity consumption.

In the Erfgoedwet[1] the protection of the archaeological heritage is embedded. Planned activities, such as the installation of a wind farm in the North Sea, may affect the archaeological values if present. If the remains are in jeopardy, there is a statutory obligation to conduct archaeological research. In line with this obligation an archaeological desk study has been carried out.

An archaeological desk study is the first step in the so-called *AMZ* cycle (Archeologische Monumenten Zorg). The *AMZ* cycle includes a description of procedures for subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands.

The second phase of the *AMZ* cycle is an inventory archaeological field study. As a rule, this field study comprises a geophysical survey of the seabed. From July to December 2022 Next Geosolutions, Shore Monitoring and Research, and DEEP BV conducted a geophysical route survey combined with a geotechnical campaign.

The survey conducted was not primarily set to provide data to be used in the course of archaeological research. However, a scan of the raw survey data proves these data to be fit for an archaeological assessment as stated in the Program of Requirements[2].

The separate phases of the AMZ-cycle are embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). This standard dictates a mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 4.

1.2 Intended cable laying operations

TenneT aims to keep the life cycle costs as low as possible when installing the cables. These costs include the financial costs for construction, management, and maintenance and for disposal, the costs for the environment and the costs of nuisance for other users of the sea. Cables are primarily protected from external threats such as towed gear and anchors by the ground cover on those cables. The seabed of the North Sea is constantly in motion. At the landfall of the cables, shedding occurs during storms, the profile of the coast and the sandbanks are constantly in motion and further out to sea, the cable routes traverse extensive areas with sand waves. Sand waves are a type of underwater dunes that can be several meters high, have a wavelength of several hundred meters and move several meters per year. If all this mobility of the seabed and of the landfall were not taken into account during the laying of the cables, a situation quickly arises during the use of the cables in which the ground cover no longer meets the requirements in places along the cable routes. Maintenance of the burial depth is then necessary. Until such maintenance is performed, the cable is exposed to an increased risk of damage from external threats. In order to keep

[1] De Erfgoedwet became effective on the 1st of July 2016.

[2] Van den Brenk and van Lil, 2021.

the life cycle costs as low as possible, TenneT has opted for a “bury and would like to forget” policy, whereby the mobility of the seabed is taken into account when determining the initial burial depth of the cables, without the cables being buried deeper than is strictly necessary.

In practice, this means that the cables on the landfall are buried between 5 and 8 meters deep, in order to be able to continue to meet the current requirements of the permits over their lifetime. The permits prescribe a permanent ground cover of 3 meters for that zone. Further out to sea, where the permits and TenneT's own policy prescribe a ground cover of 1.0 to 1.5 metres, the cables are buried in such a way that even after the migration of the sand waves in 40 years (lifespan of the cables) the ground cover still likely meets all requirements. For the areas where the cables are located in shipping routes or in the vicinity of shipping routes, there is a requirement of at least 1.5 meters of ground cover and in areas further away from the shipping routes a requirement of at least 1.0 meters of ground cover.

In order to be able to have this realized by the contractors who install the cables, TenneT defines, on the basis of seabed mobility studies, a so-called “Non-Mobile Reference Level” (NMRL) prior to the tender, which is a predicted location of the lowest seabed level for the life of the cables. In practical terms, this means that the cables in the valleys between the sand waves will be buried just over 1.0 – 1.5 meters, depending on the locally applicable requirement, and below the sand waves about as much deeper as the sand waves are high.

The available laying methods for cables at sea can be divided into dredging and burial. Burial can be divided into "simultaneous lay and burial" burial and "post lay burial" burial.

During dredging, a trench is dredged in the seabed prior to laying and/or burying the cables. The cable is then laid in that trench or buried in the bottom of that trench. The trench is filled with sediments after the cables have been laid and/or buried if this is necessary to meet the required burial depth after installation. When the cables are buried in the seabed after dredging to the required depth at installation, the dredged trench does not need to be backfilled with after installation to meet the burial depth requirements after installation. Dredging prior to cable installation is also used to reduce the influence of seabed mobility on the cable burial depth, for example by dredging mobile sand waves. In that case, the dredging prior to cable installation is called “pre sweeping”.

Burying the cable can be done at the same time as laying the cable. In that case there is talk of "simultaneous lay and burial". A cable can also first be laid on the seabed and then buried in the seabed in a separate working passage. This is called “post lay burial”.

There are various techniques for burying a cable in the seabed. In particular, the required burial depth, the composition and the strength of the sediments determine which technique can be used. In sand and less strong sediments, a cable with spray lances can be buried in the seabed. The seabed sediments are then loosened with water jets and the cable can be brought to depth. Burying cables in cohesive soils, such as heavier clay and peat, requires mechanical loosening of the sediment before the cable can be buried. A chain cutter or a cable plough pulled through the ground can be used for this.

1.3 Results desk study

In 2022 an archaeological desk study has resulted in specific information on the archaeological remains which are to be expected within the proposed cable corridor. The study has shown that (remains of) shipwrecks, WWII plane wrecks and prehistoric remains are to be expected in the area[3].

1.4 Objective

The purpose of the archaeological assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

The goals set for this assessment are:

- To determine the historical or archaeological value of contacts found in the geophysical survey;
- The validate the locations of known wrecks;
- Assess the prehistoric landscape based on the seismic data and geotechnical results.

The requirements for the archaeological assessment are defined in a Program of Requirements (Dutch: PvE)[4].

1.5 Research questions

For the archaeological field study, the following research questions have been defined in the Program of Requirements:[5]

<u>Primary question:</u>

- *Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?*

<u>With respect to side scan sonar, magnetometer and multibeam survey:</u>

- *Are there any phenomena visible on the seabed? If so: What is the description of these phenomena? Do these phenomena have a man-made or natural origin?*
- *If these phenomena can be designated to be man-made: What classification can be attached?*
- *If these phenomena can be classified as archaeological: Is it possible to interpret the nature of the archaeological objects?*
- *If these phenomena can be identified as natural: What is the nature of these natural phenomena? Based on the acoustic image is it possible to designate zones of high, middle, or low activity on the seabed? If so: How can these zones be interpreted?*

[3] Van den Brenk, van Lil and Cassée 2022.
[4] Van den Brenk and van Lil, 2022
[5] Van Lil, van den Brenk and Cassée, 2021.

General:

- *What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively? Risk-prone areas are areas where the probability of archaeological remains is considered to be high.*
- *If no acoustic phenomena can be observed: Are there any clues that this is a consequence of either natural erosion, sedimentation, or human interference?*

With respect to subbottom profiler- and sampling:

- *Based on seismic profiles and geotechnical data is it possible to map the Pleistocene landscape? If so: Can the expected buried Pleistocene units / landscapes be identified in the seismic data?*
- *What is the depth of the Pleistocene landscapes with respect to the present seabed and LAT? From Pleistocene to Holocene deposits is the transition gradual or instantaneous (erosive)?*
- *Can buried infilled channels be observed? If so: What are the characteristics of the channel structures in terms of spatial distribution (width, depth, shape, size), the composition of the channel filling, stratigraphic position, and age.*
- *Has peat / or clay been observed? If so: What is the spatial distribution (depth, extent), stratigraphic position and age of these deposits?*
- *Can zones be identified where prehistoric settlement remains can be expected? If so: Could these expected settlement remains be affected by the installation of the cables based on their vertical position related to the seabed?*
- *Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects? If so: Based on the presence of buried objects and its correlation with side scan sonar, magnetometer and multibeam data can something be said about the nature of these buried objects?*

2 Methodology

2.1 Introduction

As part of the preparations for the cable-lay operation a geophysical and geotechnical survey has been carried out by Next Geosolutions, Shore Monitoring and Research, and DEEP BV in the period July to December 2022. The objectives and the general outcome of the survey activities including the minimum technical, functional, and procedural requirements are described in the survey report[6].

The following methods have been deployed:
- side scan sonar (SSS);
- magnetometer (MAG);
- multibeam echo sounder (MBES);
- backscatter (BS);
- high resolution sub-bottom profiler (SBP);
- Vibrocores and grab sampling.

The results of the survey activities have been recorded in reports, listings, drawings, and images. The input for the archaeological assessment consists of the deliverables listed in table 5.

SSS	- event listings containing all contacts observed - georeferenced images of all contacts observed - mosaic files of all contacts listed
MAG	- event listings containing all anomalies observed
MBES	- validated *multibeam* XYZ point cloud dataset
SBP/UHR	- representative subbottom profiles - seismic unit XYZ grid data
Report	- survey reports

Table 5. Data used for the archaeological assessment

[6] Next Geosolutions 2023, document TTB_07578, see appendix 5.

2.2 Geophysical and geotechnical surveys

Geophysical surveys took place between July and December 2022 using the MPSV Levoli Cobalt, SHORE Possibility, SHORE Presence, and DEEP's SV Breaker. An overview of the survey campaign and the employed survey methods is presented in the table below.

Region	Survey Type	Vessel	Survey		Survey Methods
			Start	End	
Offshore	Geotechnical	MPSV levoli Cobalt	08-07-2022	25-08-2022	Vibrocore, Cone; Penetration Test (CPT); Grab Sampler
Offshore	Geophysical	MPSV levoli Cobalt; DEEP's SV Breaker	26-08-2022	28-12-2022	Multibeam (MBES); Sub Bottom Profiler (SBP); Side Scan Sonar (SSS); Magnetometer
Nearshore	Geophysical	SHORE Presence; DEEP's SV Breaker	10-08-2022	14-09-2022	Multibeam (MBES); Sub Bottom Profiler (SBP); Side Scan Sonar (SSS); Magnetometer
Tidal zone	Geophysical	SHORE Possibility	01-08-2022	07-08-2022	Multibeam (MBES); Sub Bottom Profiler (SBP); Side Scan Sonar (SSS); Magnetometer
Beach	Geophysical	Not applicable	12-09-2022	12-09-2022	Magnetometer

Table 6: Overview of the survey campaigns and the employed survey methods.

195 geotechnical locations were investigated during the geophysical surveys. All locations comprised a Vibro Core (VC) and Cone Penetration Tests (CPT).

Details about the geophysical and geotechnical surveys can be found in the Integrated Geophysical & Geotechnical Report in Appendix 5.

2.3 Known objects

Next Geosolutions has summarized the *side scan sonar* contacts and *magnetometer* anomalies encountered within the survey area in detailed event listings. From different databases the occurrence of objects within the area is known, as described in the desk study[7]. The contacts included in the survey event listings are compared with the database objects in the area. For this comparison four different datasets are used:

- The Hydrographic Service database (hereafter referred to as Nlhono database);
- The Rijkswaterstaat SonarReg database (hereafter referred to SR database);
- The Dutch Cultural Heritage Agency database ARCHIS;
- The Dutch Nationaal Contact Nummer database (hereafter referred to as NCN);

[7] Van den Brenk, van Lil and Cassée 2022.

The National Contact Number (NCN)

The NCN database combines the data from three governmental databases:

- The wrecks register from the Hydrographic Service of the Royal Netherlands Navy;
- The SonarReg object database of Rijkswaterstaat;
- The ARCHIS database (the official archaeological database of the Ministry of Cultural Heritage)

The permission for the use of the NCN database for the analysis was granted by the owner (Rijkswaterstaat Sea and Delta).

- The NCN database contains all basic information (E, N, and description) of the Nlhono, SR and Archis databases. More detailed information is gathered through the other datasets.

In addition to shipwrecks information on contacts referred to as 'foul' or 'obstruction' is included. From these objects the origin is not always known, but information on the location, dimensions and other valuable information is listed. Besides the databases other sources containing information on wrecks and historic finds are consulted for comparison with the survey results.

All known data is combined and plotted in a GIS. In this way an overview is made of the areas in which archaeological remains are present or to be expected. The known contacts are a reference framework for the assessment of data recorded during the route survey.

2.4 Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include *side scan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES), and high resolution subbottom profiling (SBP). The natures of those methods differ, with coherent strengths and weaknesses.

Table 7 provides a summary of the objective(s) the methods employed and the nature of those methods in terms of seabed penetration and coverage. Data are cross correlated because the methods are complementary. E.g., *multibeam* data can aid in the interpretation of a *side scan sonar* contact by providing information on its height with respect to the surrounding seabed, the occurrence of scouring next to the contact, and the accuracy and precision of the object. CPT's and borehole data can aid in the determination of geological units from seismic strata.

Method	Objective	Seabed		Accuracy and Precision	Cross Correlation
		Penetration	Coverage		
SSS	Identification of outcropping objects; seabed classification	No	Full	High	MBES / MAG
MBES	Charting of seabed morphology; identification of scours	No	Full	Very high	SSS
MAG	Identification of magnetic anomalies induced by ferromagnetic objects	Yes*1	Full*2	Accuracy = high Precision = poor*3	SSS
SBP	Identification of seismic strata and buried objects such as pipelines, cables, and boulders	Yes	No Profile data beneath sailed line	High	BH/VC/CPT*4 MAG
BH/VC/CPT*5	Determination physical properties of sediments and lithostratigraphy	Yes, max. pen.: BH 10 m VC 6 m CPT 11 m	No Point location	High	SBP

Table 7. Characteristics of geophysical and geotechnical methods employed

*1 detection dependent on size of the ferromagnetic object, depth of burial, height of *magnetometer* above the seabed and distance cross course
*2 distant objects or deeply buried objects can be missed.
*3 precision: perpendicular to ship heading = ½ * spacing of sailed lines
parallel to ship heading = appr. 1m.
*4 interpretation of geology through correlation of seismic data with VC and CPT-data, and data from the DINO database.
*5 borehole sampling was only carried out onshore.

Side scan sonar (SSS), multibeam (MBES) and magnetometer (MAG)

With *side scan sonar* all objects and structures on the seabed can be made visible. Seabed sediment of different composition can be distinguished by their characteristic reflection. *Multibeam* images reveal the morphology of the seabed. Large objects and scouring can be mapped. Smaller objects, like thin cables, or flat objects lying on the seabed often are impossible to identify in *multibeam* images.

The strength of *side scan sonar* resides in the ability to visualize (relative) differences in reflectivity of seabed sediments and exposed objects. Variations in seabed composition cannot be observed in *multibeam* data unless those variations are accompanied by morphological changes. This also applies for objects which are barely elevated above the seabed. Another strength of *side scan sonar* is full coverage accomplished with a limited amount of survey lines. A limitation of *side scan sonar* is that buried objects cannot be found with this technique.

The strength of *multibeam* lies in the high accuracy and high precision images of the seabed morphology the technique provides. Sand waves and current ripples can clearly be observed in *side scan sonar* data, but the height of those sedimentary structures can far better be established by means of *multibeam*.

However buried objects generally cannot not be traced with *multibeam*, scours caused by shallowly buried objects can lead to the identification of buried objects.

In this study *side scan sonar* and *multibeam* data were combined in the identification of objects which are of potential archaeological interest. The listing of potential archaeological objects is considered to be complete as far as it concerns exposed objects, although the presence of buried non-ferro-magnetic archaeological objects or objects which erroneously have been labelled as non-archaeological, can never be fully excluded.

Magnetometer contacts are identified by the presence of ferro-metallic objects which induce an anomaly in the earth magnetic field. These objects can be buried or lying on the seabed. Unlike *side scan sonar* and *multibeam* the contacts are tagged at the sailed survey line. The actual object can be located at both sides of the survey line. The precision parallel to the run line is in the order of one meter.

The strength of a *magnetometer* lies in its ability to trace buried objects if those objects are ferro-magnetic. The technique provides a strong tool in mapping continuous linear structures like buried cables and pipelines. Also, an indication of the presence and distribution of isolated ferro-magnetic objects in an area of investigation is obtained.
An important limitation of the *magnetometer* is the poor accuracy of the positions of the objects found. An object has to be boxed in by sailing additional lines with a *magnetometer* to pinpoint the location of the object. Further, the measured amplitude of a magnetic anomaly is dependent on the interaction of different parameters, such as the size of the object, the depth of burial, the height of the *magnetometer* above the seabed and the distance cross course. Because of this it is very hard to establish the size of the object which caused the anomaly. Thirdly buried objects cannot be seen. Therefore, it is not possible to identify the nature of the buried object.

The listing of *magnetometer* anomalies is expected to be complete as far as it concerns large ferro-magnetic objects. Due to the line spacing it cannot be excluded that especially small distant or shallow buried objects have been missed.

Next Geosolutions processed their survey data and produced detailed event listings of the *side scan sonar* and *magnetometer* contacts encountered within the survey areas.

In the course of this archaeological assessment a selection is made based on the dimensions of the reported contacts. All contacts have been assessed, and the fraction of contacts larger than or equal to four (4) meter is looked into in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. Purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

This is done by analyses of:
- *side scan sonar* images included in the survey report and digital deliverables;
- *multibeam*-data (xyz-files);
- values of magnetic anomalies reported in the survey reports;
- comparison of *side scan sonar* and *magnetometer* contacts;

The *side scan sonar* images are scanned in order to define potential archaeological sites. A selection of contacts was made of contacts to be studied in detail. The geological constellation and seabed morphology of the area are taken into account as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record. The interpretation and selection of *side scan sonar* contacts is based on best professional judgment. If desired or needed the exact nature of the contacts observed can be established with certainty through the execution of additional research by means of a ROV or divers in a following phase.

Subbottom profiler (SBP), vibrocores (VC) and cone penetration tests (CPT)
Next Geosolutions has acquired and processed shallow seismic data using a sub-bottom profiler (SBP). The processing involved an analysis of subbottom profiles and the identification and tagging of the observed seismic strata and buried objects indicated by refraction hyperbola. For this archaeological assessment the seismic strata have been interpreted and translated into lithostratigraphic units by Periplus Archeomare.
The seismic data have been used by Next Geosolutions to target specific locations for the geotechnical survey. The vibrocore and CPT locations are primarily chosen to obtain insight in the geological phenomena that could affect the cable lay operations. Periplus Archeomare was not involved in the selection of vibrocore and CPT locations. Therefore locations which could be of geo-archaeological interest have not specifically targeted. Fortunately, geological phenomena which are of interest for the cable lay operations, such as the occurrences of peat, clay, boulders, and channel infills, also are the locations one would select for geo-archaeological research.

The vibro-coring activities have been carried out at both the nearshore and offshore sector of the project.

Data from the DINO-database, TNO grid data of lithostratigraphic units, VC-logs and CPT-logs have been used as a reference framework of the geological constellation along the cable routes.

2.5 Data Analysis

Side scan sonar (SSS), multibeam (MBES) and magnetometer (MAG)
The first step in the data analysis is to cross-reference known objects within the surveyed area with the survey data. For the comparison the results of the desk study and the survey datasets were used. All the known objects were projected in a GIS together with the survey data.

For the cross-reference we have assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. The raw data was only used, when available, to verify the description of found objects and anomalies as reported.

The positions of the interpreted contacts from the different surveys were compared with the positions of the known objects collected from the databases. Besides that, all the positions of both the survey contacts and the known objects were plotted on the high resolution *multibeam* grid to visualize the morphological influence of the presence of these objects. This assisted in the determination of possible archaeological value of the present remains. If an object had a potential archaeological value, the description of the object was finalized.

Besides the objects detected from the *side scan sonar* survey also the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. For the *magnetometer* contacts that corresponded with the *side scan sonar* contacts within 50 meters of each other, these contacts were considered to be related. When at the position of the *magnetometer* anomaly no visible object was recognized the size of the anomaly was leading. If the magnetic anomaly of a contact is more than 500 nT (nano-Tesla) then it is stated that the contact could possibly be of archaeological value. All the *magnetometer* contacts above 500 nT but within 25 meters of the existing cable and pipeline routes are exempt for further investigation. It has to be stressed that within this assessment no distinction can be made between anomalies related to possible archaeological objects or anomalies related to (for example) unexploded ordnance (UXO's).

An archaeological assessment has been undertaken for all visible contacts. This interpretation is based on best 'professional judgment'.

Subbottom profiler (SBP)

The interpreted seismic data have been assessed in order to test the archaeological expectation with respect to intact prehistoric landscapes and possible related archaeological remains in the area. The archaeological desk study has resulted in the identification of lithostratigraphic units which could contain archaeological levels. The seismic images included in the Next Geosolutions Survey report have been used to get an insight into both the lateral and vertical distribution of the lithostratigraphic units and the expected archaeological levels herein. The seismic data have been correlated with information of the subsurface, including available geological data and newly obtained information from vibrocore analysis in order to test the desk study based archaeological expectation. An important factor included in the assessment is the integrity of layer boundaries because erosion by natural processes poses a significant threat to archaeological levels. Based on the assessment sections of the cable routes which are expected to contain intact prehistoric landscapes are identified. The results are reviewed in the context of the activities planned in order to predict possible influence on the potential archaeological remains.

In summary, it can be stated that the collected geophysical data meets the requirements set out in the program of requirements and are suitable for an initial archaeological analysis.

Execution

The analysis was executed from March to April 2023 by R. van Lil and S. van den Brenk (both KNA senior prospector) and R.W. Cassée (KNA Archaeologist Ma specialism Waterbodems). The analysis is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.1; protocol 4103*).

2.6 Used Sources

The following sources were used for the analysis:

- Survey data Next Geosolutions, original survey data and reported interpretations;
- Archaeological desk study Periplus (22A028-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- Nlhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN).

For a complete list of used sources and literature see the reference list at page 57.

Italic written words are explained in the glossary at page 56.

3 Results

3.1 Seabed bathymetry and morphology

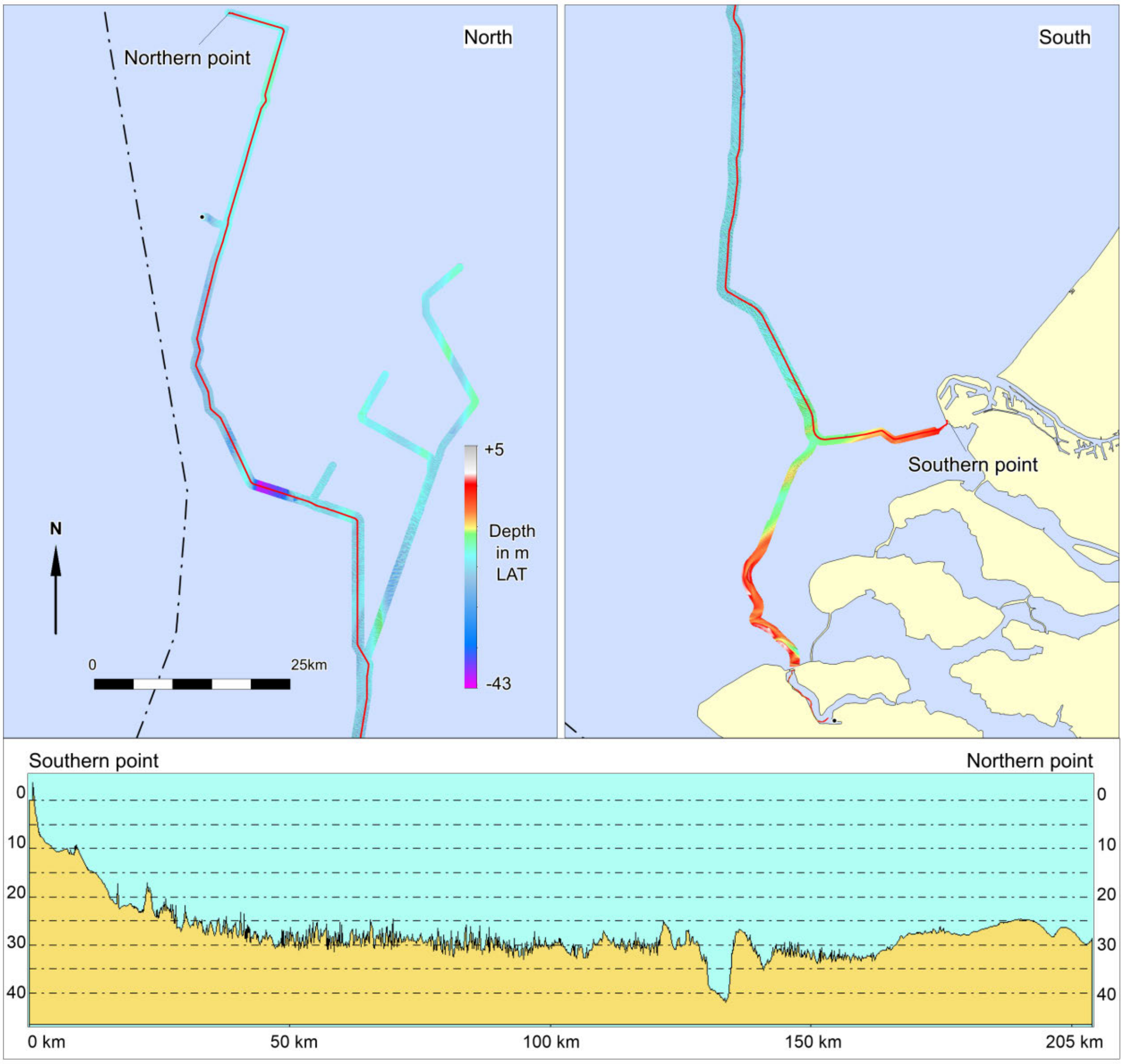

Figure 3. Bathymetry Nederwiek 2 route based on the multibeam recordings (source data: Next Geosolutions)

Based on the 2022 survey data the water depth within the research area varies from 0 to 42.8 m LAT, with an average of 26.1 m LAT.

Seabed morphology

The southern part of the offshore route is dominated by tidal ridges with a relative height of 20 meter. Along the northern part of the route, sand waves occur with a height up to 4 meters and a wave length between 150 and 350 meters. These waves have a WNW – ESE orientation and are known to migrate northwards with a speed of several meters per year[8]. Superimposed on these dunes mega current ripple bed have formed with a height up to 1 meter.

[8] Van Heeteren, 2010

3.2 Known objects: As Found positions versus database positions

Note: the results presented in the next paragraphs apply to the total surveyed area. The final impacts on the Nederwiek 2 route are summarized in chapter 5.

Based on the desk study 143 objects are known within the survey area. These objects include a (maximum) total of 21 (remains of) shipwrecks. It is possible that some of these object entries are duplicates. This is due to differences and overlaps of the different databases.

The SSS contacts and MAG anomalies encountered during this survey have been stored in event listings. The positions of the contacts and anomalies in these listings are compared with the theoretical positions of objects in the NCN database. In order to conduct this comparison all SSS contacts and MAG anomalies found within a range of 50 meters around the database locations are selected.
The outcome of this comparison can be:

- The As Found position of a shipwreck agrees with the database position of a known wreck;
- The As Found position of a contact agrees with the position of a contact listed in the database, but the interpretations do not match;
- The As Found position of a shipwreck is not in agreement with the database position of a known wreck;
- A wreck listed in the database has not been found;
- A new wreck has been found.

A summary of the As Found- versus Not Found known objects is presented in the table below.

Known Objects	**Archaeological Expectation**			**Total**
	Yes	**No**	**Unknown**	
Found	7	32	17	**56**
Not Found	5	19	30	**54**
Total	**12**	**51**	**47**	**110**

Table 8. Summary of known objects

Note: several known objects have not been found while they fall outside the surveyed area. This is because the initial investigated area for the desk study was much larger.

3.3 Side scan sonar

Next Geosolutions has identified 14321 *side scan sonar* contacts within the survey area. The classification is listed in the table below.

Classification	Survey area Alpha, Beta Gamma	 NW1&2	Total
Buoy Anchor	27	-	27
Buoy	3	1	4
Benthic Mud and Detritus	632	-	632
Exposed cable	6	-	6
Debris Anchor	-	5	5
Debris Cable	181	2	183
Debris Fish Net	5	1	6
Debris Linear	694	90	784
Debris Metallic	54	1	55
Debris Other	4045	503	4548
Debris Wire	27	17	44
Natural Feature	5701	2162	7863
Other	3	15	18
Pipeline	13	4	17
Seabed disturbance	16	-	16
Wreck	19	4	23
Total	**10758**	**4**	**14231**

Table 9. Classification of side scan sonar contacts by Next Geosolutions

58 contacts match known NCN objects. The remaining *side scan sonar* contacts and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Side scan sonar* images included in the survey report and digital provided data;
- *Multibeam*-data (0.3m grids and xyz-files);
- Comparison of *side scan sonar* and *magnetometer* contacts.

Apart from the survey data studied the geological constellation and seabed morphology of the area are taken into account as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

All contacts larger than four meters are examined in detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. Purpose of this analysis is to identify contacts that could reflect potential archaeological sites. This selection of large contacts comprises a total of 523 contacts. After examinations, 53 contacts were classified as objects with an archaeological expectation. A summary of the outcome of the detailed inspection of selected contacts is presented in the table below.

	Arch. Expectation			
Interpretation PPA	**No**	**Medium**	**High**	**Total**
Buoy	1	-	-	1
Debris	47	-	-	47
Geology	3	-	-	3
Natural feature	165	-	-	165
Piece of cable	60	-	-	60
Pipeline	3			3
Seabed disturbance	126	-	-	126
Shell bed	22	-	-	22
Unknown object	40	-	-	40
Wreck	-	8	15	23
Wreck remains	3	17	13	33
Total	**470**	**25**	**28**	**523**

Table 10. Results of the assessment of selected side scan sonar contacts

A total of 53 contacts are classified as objects with a medium (25) to high (28) archaeological expectation. Contacts with a high expectation are clear larger ship wrecks or wreck remains. Contacts with a medium expectation are smaller possible wreck remains or small wrecks which are probably recent. A complete listing of the contacts is presented below.

ID	Classification Next	Easting	Northing	Depth	NCN	Classification PPA	Survey
933	Debris linear	535914	5806494	-31.2	-	Possible wreck remains	IJvABG
1403	Debris other	536762	5807461	-30.0	13903	Possible wreck remains	IJvABG
1488	Wreck	533775	5779687	-29.2	2869	Wreck	IJvABG
1724	Debris other	535351	5771480	-28.1	-	Wreck remains	IJvABG
1903	Debris other	543918	5758747	-26.6	-	Wreck remains	IJvABG
1906	Debris other	543999	5758712	-25.3	-	Wreck remains	IJvABG
1933	Debris linear	544136	5758591	-27.4	-	Wreck remains	IJvABG
1948	Debris other	544209	5758751	-24.5	382	Wreck	IJvABG
1954	Wreck	544260	5758544	-25.7	-	Wreck	IJvABG
2060	Debris metal	546040	5755589	-23.7	-	Possible wreck remains	IJvABG
2298	Wreck	546976	5752572	-24.6	364	Wreck	IJvABG
3110	Debris other	537985	5830159	-25.8	-	Possible wreck remains	IJvABG
3149	Debris linear	540080	5837238	-32.0	-	Possible wreck remains	IJvABG
10053	Wreck	535976	5821101	-29.8	2810	Wreck	IJvABG
10059	Wreck	535882	5821036	-30.5	-	Possible wreck remains	IJvABG
10078	Debris other	535768	5834877	-27.9	-	Possible wreck remains	IJvABG
10083	Wreck	535656	5834718	-24.8	2081	Wreck	IJvABG
27085	Debris linear	540790	5737641	-22.2	-	Possible wreck remains	IJvABG
28022	Debris linear	543281	5741924	-24.4	-	Wreck remains	IJvABG
28068	Debris linear	543025	5742529	-22.1	-	Possible wreck remains	IJvABG
28228	Wreck	543296	5741910	-24.3	-	Wreck	IJvABG
40370	Wreck	548023	5708143	-15.1	-	Wreck, recent	IJvABG
40372	Wreck	544298	5713143	-16.3	-	Wreck, recent	IJvABG
40465	Wreck	544976	5712448	-9.5	-	Wreck, recent	IJvABG
40530	Debris linear	546499	5711248	-10.6	-	Possible wreck remains	IJvABG
40531	Debris linear	546471	5711261	-11.4	-	Wreck remains	IJvABG
40553	Debris other	548641	5707654	-8.7	-	Possible wreck remains	IJvABG

ID	Classification Next	Easting	Northing	Depth	NCN	Classification PPA	Survey
40812	Debris linear	545032	5712482	-8.8	-	Possible wreck remains	IJvABG
40817	-	544969	5712546	-9.4	-	Wreck remains	IJvABG
42231	Wreck	544305	5717781	-4.9	1670	Wreck	IJvABG
43101	Wreck	538996	5722986	-11.9	-	Wreck	IJvABG
43103	Wreck	541871	5720092	-13.9	-	Wreck	IJvABG
60125	Debris linear	547506	5709051	-13.8	-	Possible wreck remains	IJvABG
65017	Wreck	538034	5727082	-0.4	9339	Wreck	IJvABG
440161	Debris linear	538263	5723739	-10.4	-	Possible wreck remains	IJvABG
450041	Wreck	538796	5727655	-9.1	-	Wreck	IJvABG
450063	Wreck	537778	5728407	-9.0	-	Wreck	IJvABG
450128	Wreck	538786	5727670	-7.7	9316	Wreck	IJvABG
450153	Wreck	538420	5728758	-7.4	192	Wreck	IJvABG
2140014	Debris other	547442	5855149	-30.5	-	Possible wreck remains	IJvABG
2150001	Wreck	546418	5867040	-25.8	-	Possible wreck remains	IJvABG
2150002	Wreck	546385	5867084	-25.9	-	Possible wreck remains	IJvABG
SSS_BRK_11012	Debris Linear	540808	5767868	-27,7	-	Possible wreck remains	NW12
SSS_BRK_11020	Debris Other	542369	5764697	-28,5	-	Possible wreck remains	NW12
SSS_COB_00438	Debris Other	526488	5847207	-35,1	-	Possible wreck remains	NW12
SSS_COB_00461	Debris Linear	524100	5847759	-40,7	-	Possible wreck remains	NW12
SSS_COB_00463	Debris Other	524040	5848843	-40,5	-	Possible wreck remains	NW12
SSS_COB_00536	Debris Other	519571	5854937	-34,0	-	Possible wreck remains	NW12
SSS_COB_02273	Debris Fish Net	525796	5907245	-27,8	-	Possible wreck remains	NW12
SSS_BRK_11019	Wreck	542324	5765516	-25,1	24	Wreck	NW12
SSS_COB_00642	Wreck	518981	5881679	-27,7	1211	Wreck	NW12
SSS_COB_00655	Wreck	518956	5881687	-27,2	1211	Wreck	NW12
SSS_COB_00654	Wreck	518972	5881684	-27,2	1211	Wreck	NW12

Table 11. Listing of sites with an archaeological expectation

Detailed description and images of the contacts are presented in Appendix 1. A number of representative examples are presented on the next pages.

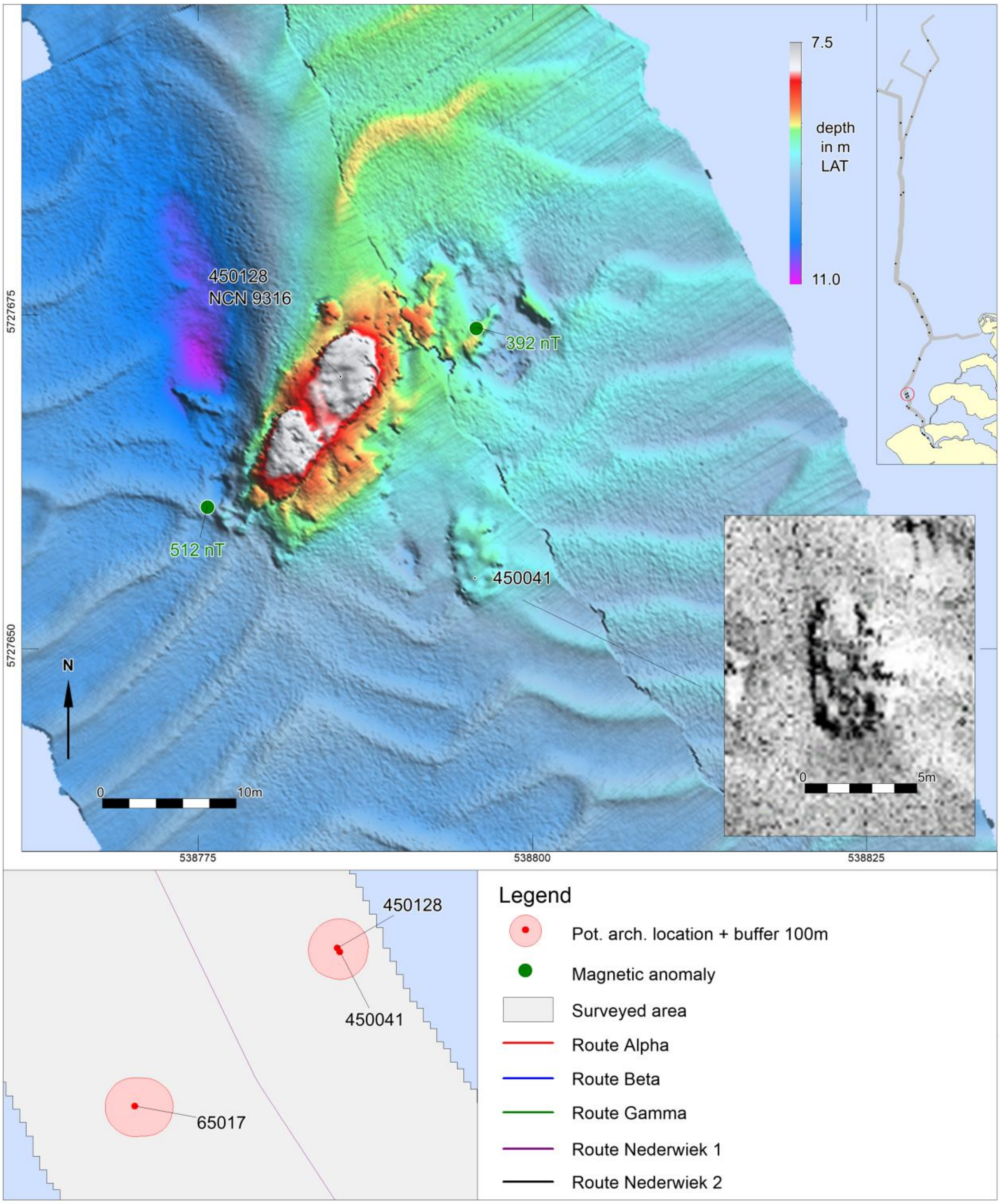

Figure 4. Example of contacts 450041 and 450128

Contact 450128 represents the site of NCN 9316, a historic wreck with toponym *Schouwen Banjaard 1* The site is known at RWS under "spot at point 11, three-master". According to sports divers the cargo consists of rolls of iron of 60-70 cm length. Ten meters south of the wreck a smaller oval object is clearly visible (contact 450041) which might be the remains of a small wreck, possibly a dinghy or skiff. The site has been recorded before in 2020 with side scan sonar and multibeam[9].

[9] Van den Brenk and van Lil, 2021

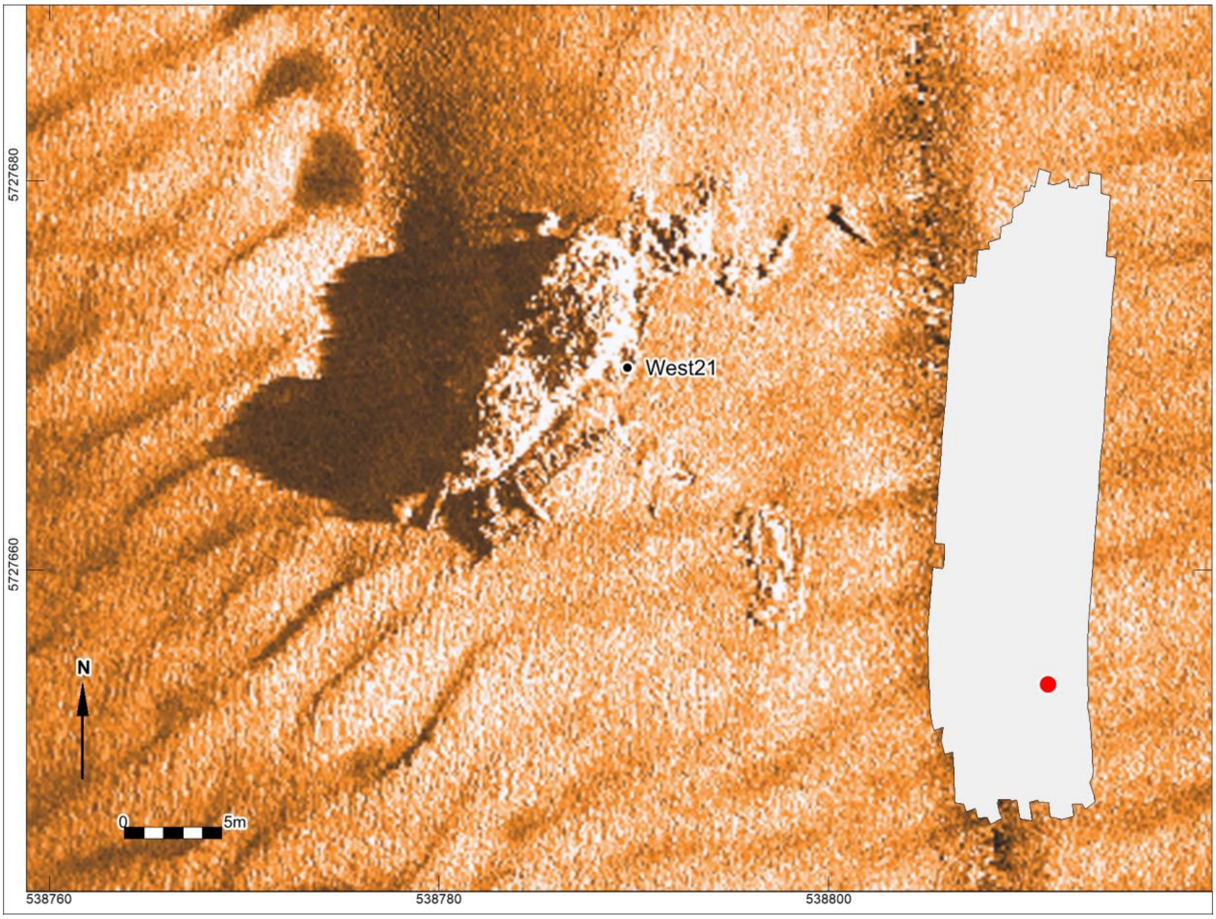

Figure 5. Sonar image of NCN 9316 during the 2020 survey

Magnetic anomaly 65017 represents the site of the *SS Rival*. This was a German steam freighter, on its way from Kiel (Germany) to Gent (Belgium) with a cargo of flax and hemp. It stranded on the *Banjaard* on 7-12-1886. Divers reported in 1887 that the wreck, laying at a depth of seven meters was buried in sediment[10]. During a 2020 survey, the water depth at the location was to 2.6m LAT, and in the 2021 survey the water depth was reduced to only 0.3 meter. Side scan sonar images do not show any signs of the wreck at the seabed surface, but large magnetic anomalies pints out the location of the wreck (see figure below).

[10] Marhisdata

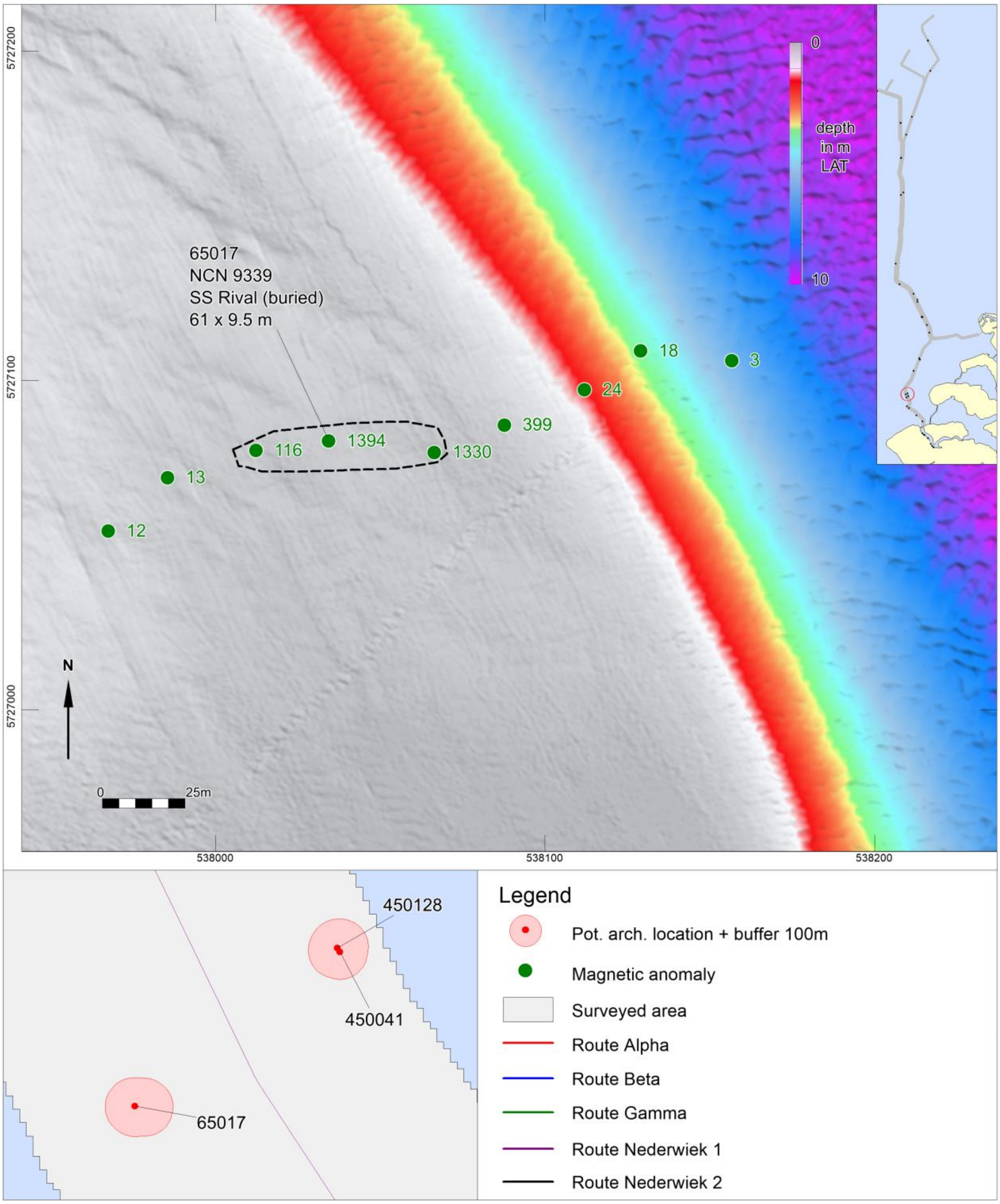

Figure 6. Example of contact magnetic anomaly 65017, buried remains of Rival.

3.4 Multibeam

Apart from the *multibeam* images discussed in the previous sections no *multibeam*-features have been observed which are interpreted to reflect the presence of archaeological objects or structures.

3.5 Magnetometer

Besides the objects that are visible on the sea bed and are selected as of possibly archaeological value there also are large *magnetometer* anomalies which are not observed on the *side scan sonar* or *multibeam* data. A number of these anomalies can be related to infrastructure (cables and pipelines), but the majority have an unknown origin. Although the nature of these objects is not known it is possible that the anomalies represent archaeological remains buried in the seabed, and therefore have to be taken into account within this assessment. The average line spacing for the magnetometer was 25 meters. a minimum value of 500 nT has been used to classify the objects as potentially archaeological targets.

Note on magnetic anomalies and value of 500 nT.
A magnetic anomaly is a local deviation from the natural magnetic field, expressed in nanoTesla. The measured value depends on the mass of the iron contained by an object, but also largely on the distance between magnetometer and the object. With a relatively large line spacing (>= 100m) chances are, that objects are missed or have an apparent lower reading on the magnetometer.

For example: a mass of 1000 kg iron results in a value of 50 nT at 12 meters, and 500 nt at 5 meters. The term 'large anomaly' is therefore subjective and depends mainly on the line spacing of the magnetometer survey.

For archaeological assessments, as a rule of thumb, the following minimum values for unidentified deviations are therefore considered to be of archeological interest:
Line spacing ~100 meters: 50 nT
Line spacing ~50 meters: 500 nT

A total of 12663 magnetic anomalies have been observed within the area of investigation. A classification is listed in the table below.

Classification	Survey area		Total
	Alpha, Beta Gamma	NW 1 & 2	
Cable	584	759	1343
Pipeline	131	113	244
Wellhead		2	2
Unknown	7663	3396	11059
Wreck	11	4	15
Total	**7674**	**4274**	**12663**

Table 12. Classification of the magnetic anomalies

At total of 1580 magnetic anomalies can be associated with known infrastructure (cables, pipelines, and wellheads). 15 anomalies are related to wrecks.

A total of 11059 magnetic anomalies cannot be related to known pipelines and cables, probable cables marked by aligning anomalies or visible objects at the seabed surface. These anomalies are related to unknown ferrous objects buried in the seabed, covered by sediments. 87 of the magnetic anomalies related to unknown (buried) objects have peak-to-peak values of 500 nT or more. Those 87 anomalies are considered to be of potential archaeological interest.

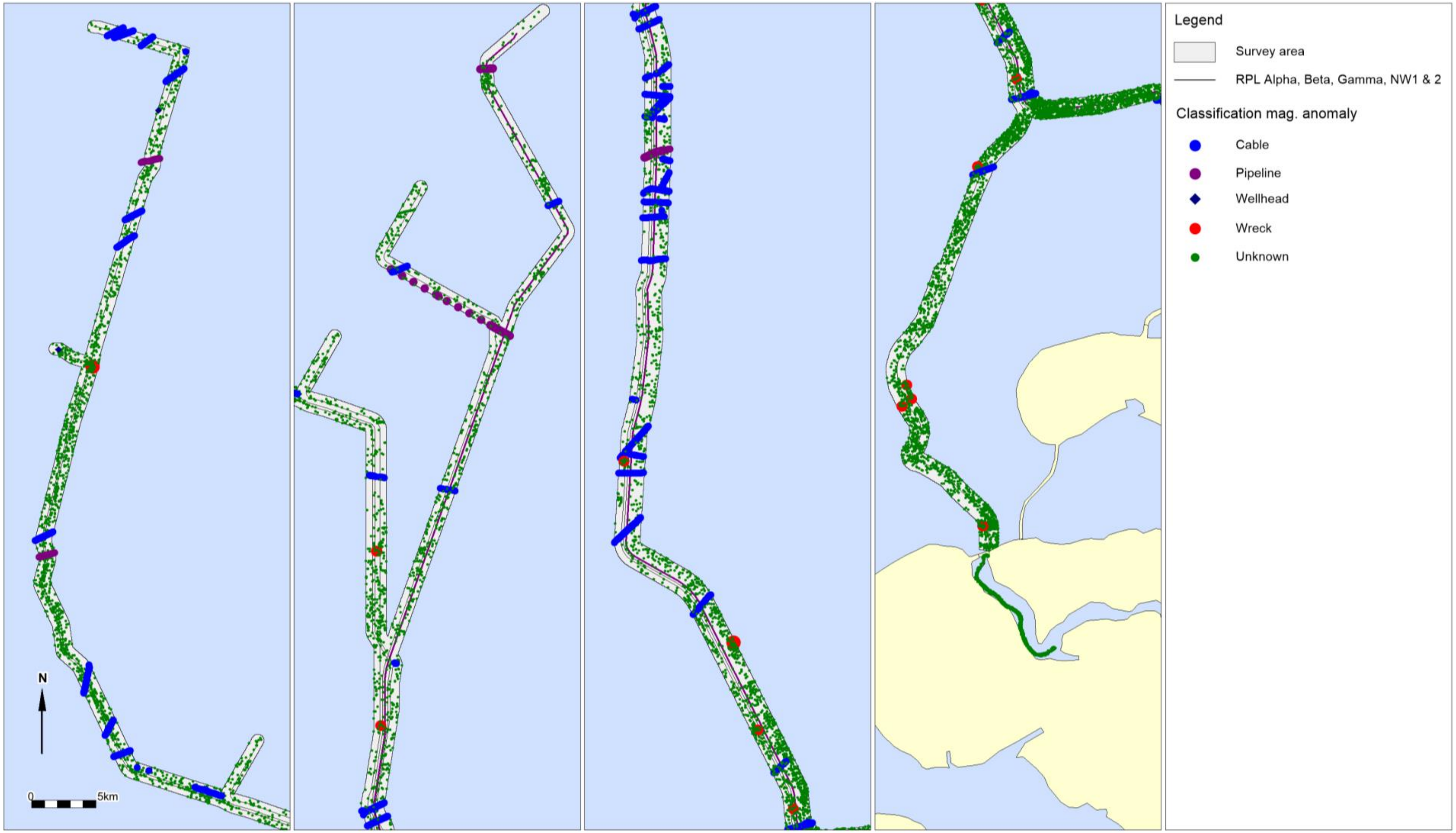

Figure 7. Classification of the magnetic anomalies

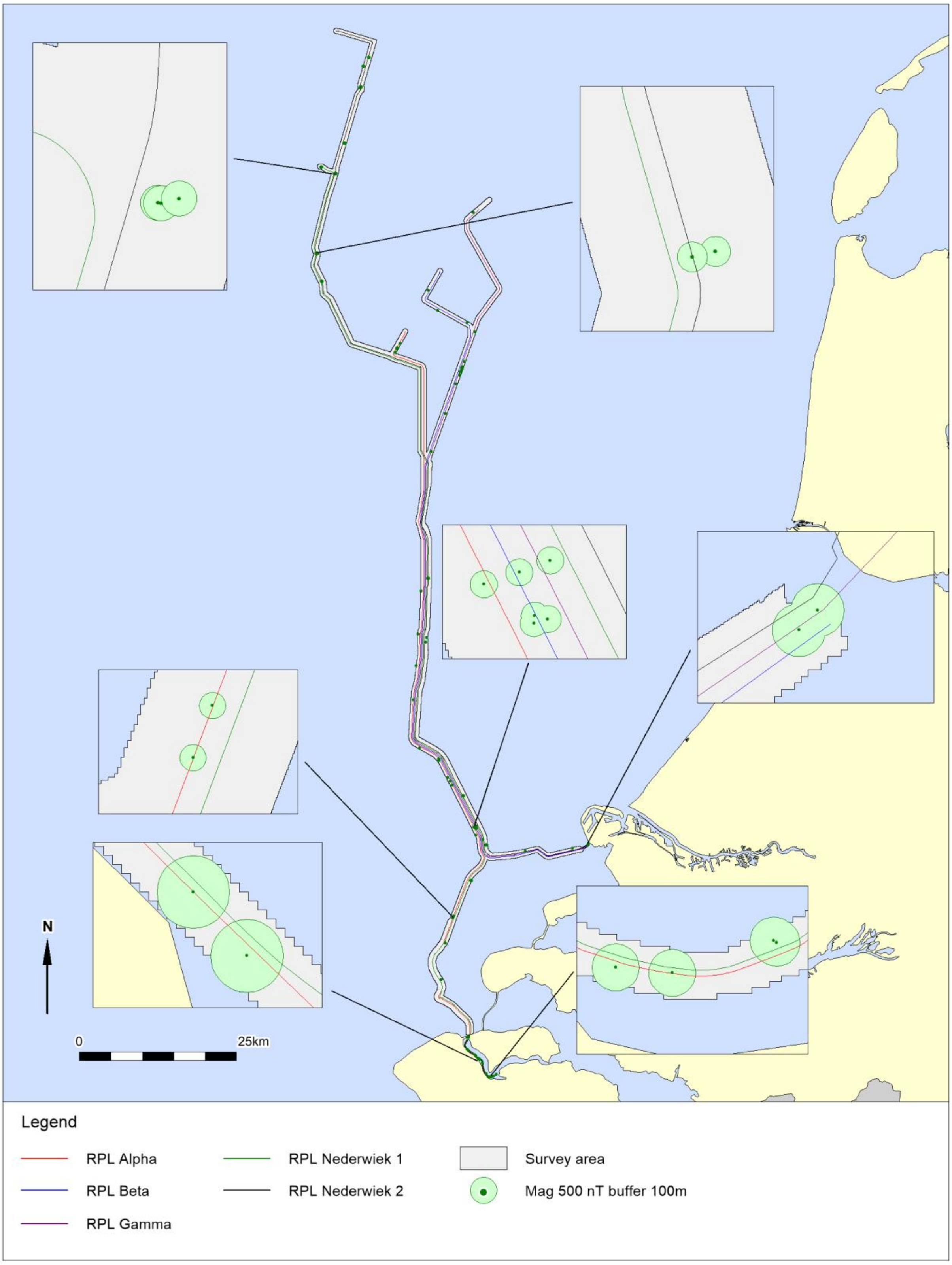

Figure 8. Overview of the magnetic anomalies peak-to-peak values of 500 nT or more

3.6 Subbottom data

The Next Geosolutions survey report[11] contains fifteen seismic images to illustrate the geological constellation along the proposed Nederwiek 2 cable route.

Seismic reflectors represent horizons that mark a sudden change in the physical properties at the interface between two layers of different composition[12]. Along the cable route seismic reflectors have been digitized that either define the boundaries between sedimentary units with different seismic and lithological characteristics or represent phenomena that due to their physical properties could affect the installation of the cable.

The seismic reflectors have been interpolated into grids. These grids have been delivered to Periplus Archeomare as raster geotiffs and xyz text files with elevations in m relative to LAT and depths in m relative to the seabed.

The digitized horizons are:

- Base of Mobilised Sediments;
- Base of Layered Sediments;
- Top of Layered Sediments;
- Peat and Clay;
- Paleochannel.

To understand which lithostratigraphic units the observed seismic phenomena represent, the Next Geosolutions data are combined with data from additional seismic and geological sources. These additional data include:

- TNO grid data of geological units in the North Sea area (2003);
- TNO grid data of the top of the Pleistocene (2007);
- UHRS data collected by GEOxyz within the IJVWFZ (2021);
- DINOloket subsurface data (2022);
- Top Pleistocene Map (Laban, 2004);
- Geological Maps 1:250 000 series Indefatigable (1987), Flemish Bight (1984) and Ostend (1991) (British Geological Survey and Geological Survey of The Netherlands);
- Geotechnical data (VC and CPT) collected by Next Geosolutions along the route;
- Brenk, S. van den, and R. van Lil, 2023. Net op Zee IJmuiden Ver (Alpha) – An archaeological assessment of geophysical & geotechnical survey results. Periplus Archeomare Report 21A001-02.
- Hijma, M.P., K.M. Cohen, W. Roebroeks, W.E. Westerhoff and F.S. Busschers, 2012. Pleistocene Rhine-Thames landscapes: geological background for hominin occupation of the southern North Sea region;

[11] Next Geosolutions 2023, document TTB-07689-Final Report.

[12] A seismic reflector marks a sudden change in the so-called 'acoustic impedance' of the sediment beds. The acoustic impedance of a layer = sound velocity with which an acoustic wave travels through this sediment (V) * the density of the sediment (ρ).

- Zagwijn, W. H. 1983 Sea-level changes in The Netherlands during the Eemian. In: M. W. van den Berg & R. Felix (eds.): Special issue in the honour of J. D. de Jong - Geol. Mijnbouw 62: 437-450.

Major part of the Net op Zee Nederwiek 2 cable route runs parallel to sections of the Net op Zee IJmuiden Ver (Alpha), (Beta) and (Gamma) cable route trajectories[13]. Along these cable routes geological cross-sections have been produced that are also representative of the geological constellation along the Nederwiek 2 cable route. These geological cross-sections cover parts of the cable route which are discussed below. In the following sections IJmuiden Ver (Alpha), IJmuiden Ver (Beta) and IJmuiden Ver (Gamma) are abbreviated to IJV (Alpha), IJmuiden Ver (Beta) and IJV (Gamma). The KP's mentioned refer to the respective IJmuiden Ver cable routes unless explicitly is referred to the Nederwiek 2 route.

IJV (Gamma) section KP0 – KP22 | Nederwiek 2 section KP0.0 – KP21.73 (estimated)
From the landing point of the IJV Gamma cable at the Maasvlakte coastline westward (KP0 - KP7) the geological profile is characterized by a thin (0.0 m to 1.5 m) top layer of mobile sand. The base of the mobile layer is traced by Next Geosolutions in major part of the KP0 – KP22 section. This sandy upper unit is classified as the Bligh Bank Member | Southern Bight Formation. The Bligh Bank Member unconformably covers Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation.

Based on TNO | Geological Survey of The Netherlands grid data of both geological units and the top of the Pleistocene sequence the Wormer Member is expected to be more than 5 m thick in the KP0 - KP17 section of the cable route.

Figure 8-45 of the Next Geosolutions Nederwiek 2 survey report indeed shows clear parallel reflectors that relate to alternating beds of clay and fine sand of the Naaldwijk Formation | Wormer Member (see figure 9 below). These deposits are labelled in this figure as 'Holocene upper sequence (prograding estuarine deposits and modern channels)'. The pinkish wiggly horizontal lines that are displayed at regular intervals below the seabed mark the 3 m intervals below the seabed, thus providing some idea on the vertical scale. The base of the Wormer Member is indicated with a yellow line that marks the boundary with the underlying unit that is characterized by a chaotic seismic facies. At some 4 m to 5 m below the seabed a subhorizontal reflector is digitized with a green line. In the top left part of the image the yellow line defines a mound-like structure in the subsurface. The subparallel beds of clay and sand of the Wormer Member appear to be onlapping on this mound-like phenomenon. To the right of this mound-like feature (= to the west) the yellow line is intermittent at approximately 1 meter below the seabed.

We interpret the mound-like feature as a possible Early Holocene river dune (indicated with a brown dashed line in see figure 9). The wind-blown deposits of this river dune are classified as the Boxtel Formation | Delwijnen Member. To the west of the possible river dune the intermittent part of the yellow line marks a section where the presumed river dunes have been truncated by erosion. This has resulted in a subhorizontal erosional plane at the top of a chaotic seismic facies. The mound-like feature that we interpret as a river dune resembles a river dune complex that has been investigated in the Yangtze harbour (see figure 10).

[13] Nederwiek 2 from KP0 (shore) to KP158.

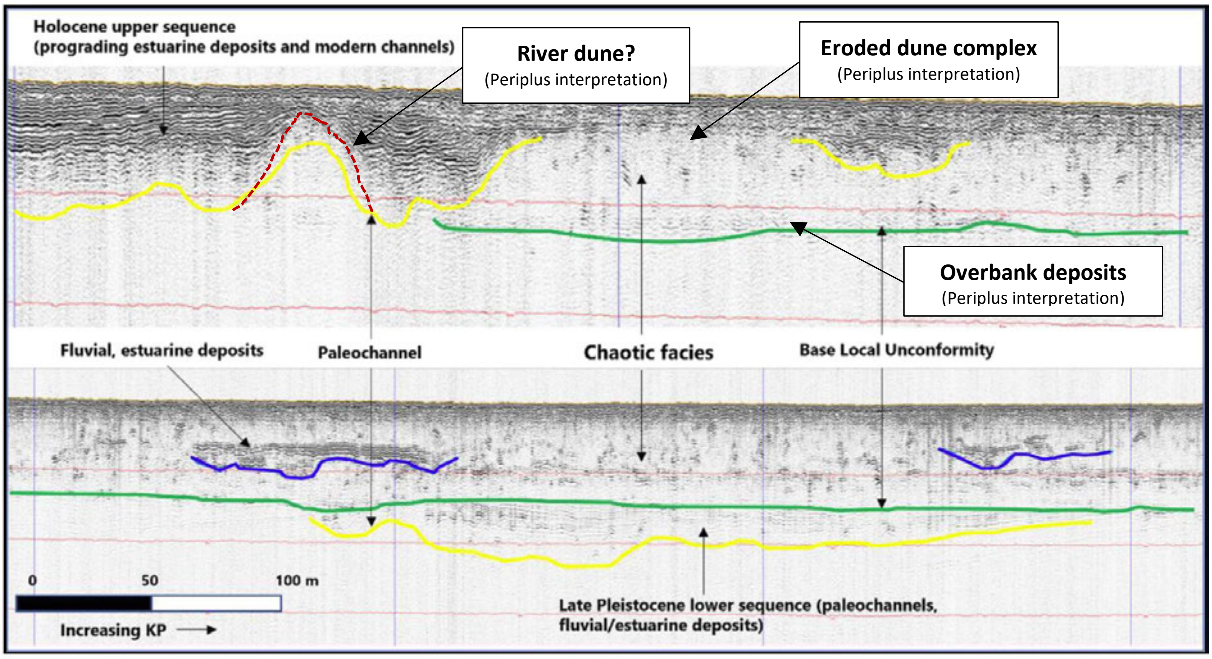

Figure 8-45 SBP results from NW2 KP 2.0 to NW2 KP 10

Figure 9. Next Geosolutions NW2 survey report figure 8-45 'SBP results from NW2 KP 2.0 to NW2 KP 10'

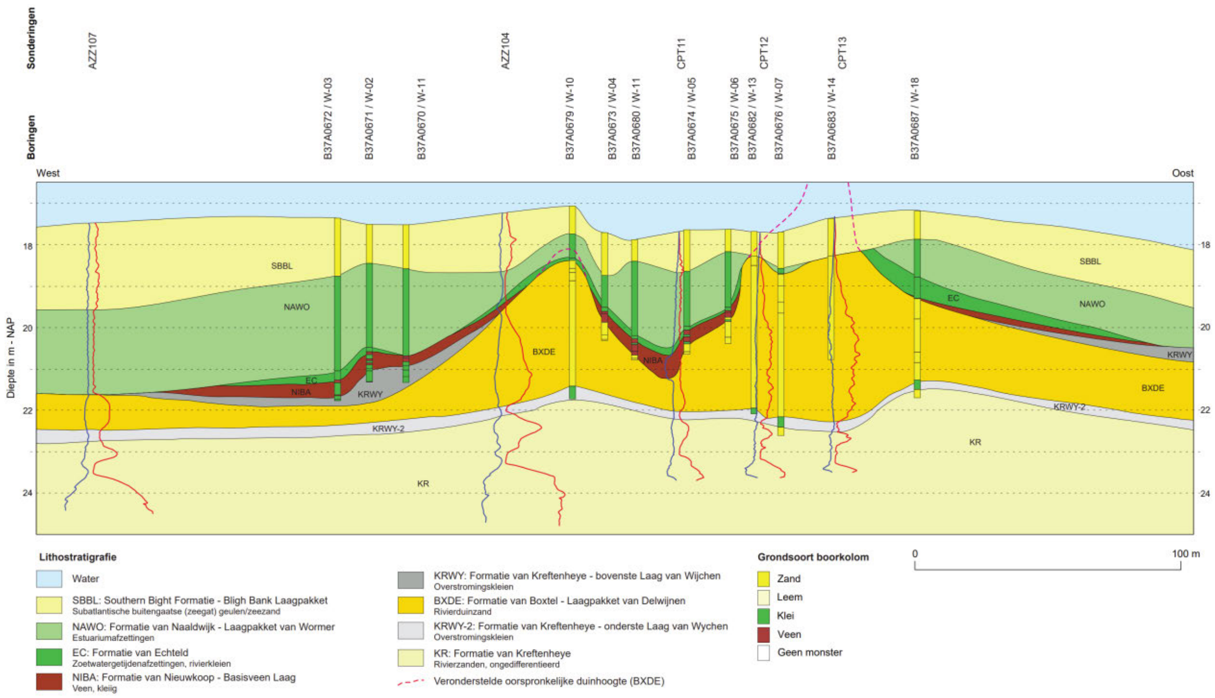

Figure 10. River dune in Yangtze harbor (from: Sier and Moree 2011.)

This Yangtze harbour river dune was used by Early Mesolithic a hunter-gatherer family or families for the installation of a basecamp-like settlement. Possibly, the dune was used over a longer period, with recurrent and/or seasonal occupation.

Figure 10 shows that in the Yangtze harbor Late Glacial sandy river deposits of the Kreftenheye Formation are covered by a continuous bed of Early Holocene overbank deposits of the Wijchen Bed| Kreftenheye Formation (KRWY-2). These overbank deposits consist of laminated grey loam, sandy clay and clayey sand. The Wijchen Bed was deposited during periodic flooding of the Rhine | Meuse. Due to exposure of the Wijchen Bed at the surface soil formation has taken place. The soil formation and ripening resulted in the firm to stiff bed with paleosols we find to date. At the onset of the Holocene, between 9.1 ka and 8.9 ka BC, the overbank deposits of the Wijchen Bed were covered with fine sand that was blown from the dry riverbed and deposited on the bordering floodplain as dunes.

In the nearshore section, from KP0 to KP7.7 (KP0 to KP8.0 of the Nederwiek 2 cable route), an area is crossed where Early Holocene peat of the Basal Peat Bed | Nieuwkoop Formation and Early Holocene fresh/brackish water clay of the Echteld Formation have been mapped by Hijma.[14] These beds of fresh-water peat and clay have been found in the Yantze harbor (see figure 10). The Basal Peat Bed and Echteld Formation occur around or below -20 m LAT. Within the KP0 to KP7.7 section, from KP5.1 – KP7.4, Hijma mapped a channel system that was active around 8500 BP.

Next Geosolutions mapped possible peat occurrences from KP3.6 – KP6.8, and channels features from KP4.4 – KP6.6 in the IJV (Gamma) route trajectory. Although the channel features are located a little east from the Hijma mapping, these channels are likely to comprise the 8500 BP Rhine Meuse channel system. The possible peat layers are found around -12.6 m LAT, at 2 to 3 m below the seabed. The presence of peat is not supported by the vibrocore samples which are taken. However, this does not mean that local occurrences of peat might be present, and gas bearing levels do occur within the channel system. Possibly, peat occurs as a local residual channel infill. Such peat layers are part of the layered Wormer Member channel infill deposits, and not classified as the Basal Peat Bed.

It is difficult to pin-point the exact location of the interpreted river dune based on the image contained in the Next Geosolutions Nederwiek 2 survey report. The seabed elevation between KP2.0 and KP10 of the Nederwiek 2 cable route trajectory ranges from approximately -8 m to -11 mLAT. This implies that the top of the Pleistocene deposits (green 'Basal Local Unconformity') is located around -12 m to -15 mLAT and the top of the interpreted river dune at -9 m to -12 mLAT. If is indeed proves to be the case, both the top of the Pleistocene rivers sands and interpreted river dune appear to occur at a higher elevation (= shallower depth) than is to be expected based on available geological data. These questions can be resolved through additional research, for instance in the form of vibrocore analyses. The penetration depth of a vibrocorer (6 m) should suffice to sample both the top of the Late Glacial river sand of the Kreftenheye Formation, loamy and clayey overbank deposits of the Wijchen Bed, river dune sands of the Delwijnen Member | Boxtel Formation and possible covering beds of peat of the Basal Peat Bed and river clay of the Echteld Formation, if present.

From KP14 – KP22 the IJV Gamma cable route crosses an area where Early Holocene fresh/brackish water clay of the Echteld Formation has been mapped.[15] This section coincides with the cable route section where multiple channels incisions have been identified and mapped by Next Geosolutions. The Echteld

[14] Hijma 2012.
[15] Hijma 2012.

Formation consists of a firm to stiff silty clay that covers the Pleistocene deposits of the Kreftenheye Formation, the Boxtel Formation and the Early Holocene Basal Peat Bed. The clay bed predates the channel incisions of the Wormer Member and has been found in one of the vibrocore samples: VC_227_A. Possibly, the clay bed of the Echteld Formation has been eroded by the younger tidal channels which are infilled with fine sand and silt.

Between KP21 – KP22 sub-cropping Pleistocene river deposits of the Kreftenhye Formation are found at shallow depths below to the seabed; locally the Kreftenheye Formation could even be found exposed at the seabed surface. This particularly is the case in the low-lying areas in between sand waves. The TNO top Pleistocene grid data (2007) differ from the TNO Top Kreftenheye Formation grids (2003), in that, the Top Pleistocene grid data indicate that the top of the Pleistocene (= Kreftenheye Formation) already occurs westward from KP15.8 at shallower depths (refer to geological profile from KP0 to KP22 in appendix 1).

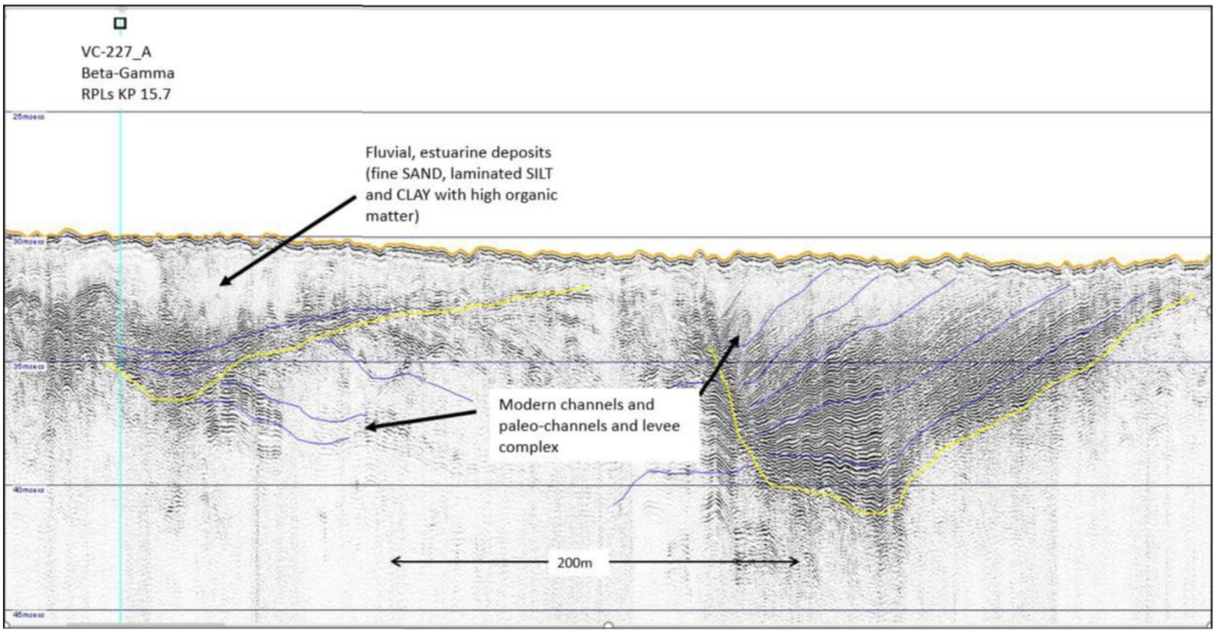

Figure 11. IJV (Gamma) SBP example section KP15.5 – KP16.0 (source: Next Geosolutions survey report)

The Pleistocene river deposits of the Kreftenheye Formation possibly are sampled in the vibrocores from KP15 westward. The Weichselian and Early Holocene landscapes which are known containers of prehistoric remains include cover sand ridges and river dunes of the Boxtel Formation, and river deposits of the Kreftenheye Formation. These levels will not be affected by the installation of the cable within the KP0 – KP15 section of the cable route.

Valuable information on the Early Holocene development of both aquatic and terrestrial landscapes can be obtained from vibrocore VC_227_A, in which – possibly – a sequence of the Kreftenheye Formation (Late Pleistocene river sand), the Echteld Formation (Early Holocene fresh or brackish water clay) and the Naaldwijk Formation (Early Holocene laminated tidal silt) occurs.

Another vibrocore which could provide information of the evolving landscape, is vibrocore VC_238_A, which contains the laminated infill of a channel that presumably was active around 8500 BP. Information on the actual activity of this channel system could be obtained through the analysis of samples taken from this infill.

IJV (Gamma) section KP22 – KP50 | Nederwiek 2 section KP21.73 – KP49.51 (estimated)
The geological profile of the KP22 – KP50 section of the IJV (Gamma) cable route shows a rather homogenous pattern. The seabed is characterized by well-developed sand waves. Some sand waves are more than 5 m high. From KP22 – KP30 the top of the Pleistocene landscape lies just beneath the seabed in the valleys in between the sand waves. From KP30 – KP50 the mobile sandy top layer of the Bligh Bank Member becomes thicker. In most places, the Bligh Bank Member unconformably overlies sandy river deposits of the Kreftenheye Formation. The seismic character of the Kreftenheye Formation is described as 'opaque'.

The top of the Kreftenheye is lies within the sample interval of most vibrocores. An exception is the ridge-like occurrence of the Naaldwijk Formation, from KP21.5 – KP 24.5. This sediments of this ridge are sampled in the vibrocores VC_175_A and VC_176_A. The ridge appears to be part of the Zeeland ridges, which comprise sand bars which formed in prehistoric times. In VC_176_A the ridge consists of yellowish medium sand which covers soft clay. The top of the clay is found at 4.61 m below the seabed. Analysis of the clay layers and the actual sands from which the ridge is built could provide information on the (timing of the) development of the Zeeland ridges.

The Kreftenheye Formation wedges out towards KP 50, the end of this geological profile. Here, Early Pleistocene fluvial and estuarine deposits of the Yarmouth Roads Formation are found at shallow depths. The Yarmouth Roads Formation is mostly covered by a thin layer of the Eem Formation. Based on the TNO grid 2003 data, the Bligh Bank Member is expected to be more than 5 m thick, because of which the top of the Pleistocene sequence lies just below the penetration depth of the vibrocorer. On the 1984 Flemish Bight Map, the Elbow Formation is mapped. The Elbow Formation is an old name for Early Holocene laminated deposits (fine sand, silt and clay) and a basal peat, which currently are classified as the Wormer Member | Naaldwijk Formation and the Basal Peat Bed | Nieuwkoop Formation.

IJV (Gamma) section KP50 – KP80 | Nederwiek 2 section KP49.51 – KP79.54 (estimated)
From KP50 – KP61 this profile shows a continuation of the stratigraphy in section KP20 – KP50. Beneath the base of the sand waves the Bligh Bank Member is some 5 m thick. It is considered likely, that the basal part of this layer, which for now is mapped as Bligh Bank Member, locally consists of Early Holocene deposits of the Wormer Member. Towards the north the number of channel features that have been mapped by Next Geosolutions increases. Presumably the age of these channels is Holocene, although the exact timing of incision is not known.

The top of the Pleistocene sequence below this Holocene cover consists of marine deposits of the Eem Formation, including (greenish) grey fine to medium calcareous sand with local intercalations of clay. The Eem Formation has been deposited during the Eemian interglacial, approximately 130 ky – 115 ky ago. At the top of the Eem Formation the Brown Bank Member occurs. The Brown Bank Member consists of brackish lagoonal to stream-fed lacustrine clays, which mark the Early Weichselian regression in the North Sea area. The Brown Bank Member consists of consolidated (stiff) greyish brown to greyish green silty clay, with fine sand in laminae and desiccation cracks. The silty clay can be extensively bioturbated and locally cryoturbated, desiccated and rooted at the top, with soil horizons.[16]

From KP61 – KP80 the Eem Formation thickens. From KP62.7 – KP72.1 the Kreftenheye Formation reappears in the profile. This occurrence is based on the 2003 TNO grid data. However, the stratigraphic position of the Kreftenheye Formation, in between the Eem Formation and the Brown Bank Member, is remarkable. The presumed Kreftenheye Formation is not reached by the vibrocorer, so no further information can be obtained from this unit.

In between the Bligh Bank Member and the Brown Bank Member at the top of the Pleistocene, a sequence of layered sediments has been mapped by Next Geosolutions. The thickness of this sequence increases northward. CPT logs indicate that from KP71.5 – KP 80 the top of this unit is located just below the base of the sand waves. The shallow occurrence of this unit is reflected in a change of the sand wave morphology; they become significantly smaller.

The lithostratigraphic unit to which these deposits shall be attributed to is uncertain. The sequence is likely to include tidal deposits of the Early Holocene Wormer Member | Naaldwijk Formation. However, it can certainly not be excluded that the layered sequence (also) includes Late Glacial – Early Holocene stream deposits of the Singraven Member | Boxtel Formation, local occurrences of cover sand deposits of the Wierden Member | Boxtel Formation and laminated stiff silty clay of the Brown Bank Member | Eem Formation. Analysis of sediment intervals from the vibrocores (e.g. VC_125_A and VC_126_A) could provide information on the actual character and genesis of the deposits.

IJV (Alpha) section KP110 – KP140 | Nederwiek 2 section KP77.58 – KP108.10 (estimated)

The abovementioned 'unknown unit' occurs over the full extent of the KP110 – KP140 section. The top of the Pleistocene sequence, which is based on 2007 TNO Top Pleistocene grid data, lies much closer to the seabed than the top of the Pleistocene sequence that is represented by the Brown Bank Member. The Brown bank Member in the geological profile is based on 2003 TNO grid data. The difference ranges from 2 m to 5 m. Actually, the top of the Pleistocene units indicated by the 2007 TNO Top Pleistocene grid data coincides with the top of the unknown unit, adding to the question if this unknown unit indeed consists of deposits of the Naaldwijk Formation, or for instance comprises older Late Glacial to Early Holocene stream deposits of the Singraven Member. As mentioned before, the lower parts of what is classified as the Bligh Bank Member can also include early Holocene deposits such as tidal deposits of the Wormer Member. In that respect VC_115_A displays an interesting stratigraphy. In this vibrocore a peat bed is found at 0.30 m to 0.73 m below the seabed. Given a water depth of -30.34 m LAT, the peat bed lies at -30.64 m to -31.07 m LAT. Based on available sea level curves this peat bed must have been deposited some 10 cal. ky BP[17]. The underlying sequence of medium grey sand, which contains roots of the plants, is no part of the Bligh Bank Member. What the age and origin of this sandy sequence is can be determined through further analysis.

[16] TNO-GDN (2022). Brown Bank Member. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands.

[17] Vink 2007.

It can be seen in the profile that the occurrence of the unknown unit is not limited to the laminated sediments that have been mapped by Next Geosolutions. The top of the unknown unit is also interpreted based on CPT data.

From KP128.5 northward Next Geosolutions mapped several channel features in the deposits overlying the layered sediments. In this part of the profile the top the unknown unit is sampled in the lowermost parts of the vibrocores.

IJV (Alpha) section KP134 – KP164 (deviation from Nederwiek 2 route around KP158.2)
Nederwiek 2 section KP KP108.10 – deviation from IJV (Alpha) route around KP125.9 (estimated)
The final section of the IJV (Alpha) cable route shows a large number of sand waves and a flat-top ridge from KP152.7 - KP157.0. The ridge is 5.4 m high and 4.3 km wide.

In 2021 GEOxyz performed a seismic survey with Ultra High Resolution Seismics (UHRS) in the IJmuiden Ver Wind Farm Zone. GEOxyz presented the results of this seismic survey in alignment charts, which are disclosed via the website of The Netherlands Enterprise Agency (RVO)[18]. The seismic data show a high resolution and clear reflectors within the boundaries of the IJVWFZ.

Based on our interpretation the seismic data the following units are likely to be present (from bottom to top):
- Glacially deformed sediments of the Yarmouth Roads Formation;
- Layered marine sediments (predominantly sand) of the Eem Formation;
- Layered and laminated brackish lagoonal to stream-fed lacustrine silt and clay of the Brown Bank Member | Eem Formation;
- Late Glacial and Early Holocene small-scale fluvial silt and fine sand of the Singraven Member | Boxtel Formation;
- Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation;
- Current mobile sandy sediments of the Bligh Bank Member | Southern Bight Formation.

The Eem Formation including the Brown Bank Member are in most places truncated by overlying younger deposits of the Singraven Member and/or Wormer Member (erosional contact). It is uncertain if the vibrocores have reached the Brown Bank Member. The vibrocore content predominantly shows alternations of sand laminae with a variable admixture of silt, organic material, clay, and occasional shell fragments. Analysis of specific sample intervals of (part) of the vibrocores discussed above, would provide valuable information on the development of aquatic and terrestrial landscapes in this part of the IJV Alpha cable route trajectory during the Eemian, Weichselian and Early Holocene, and would clarify the actual lithostratigraphic units which are present.

Nederwiek 2 parallel section to Nederwiek 1: KP125.9 - KP169.6 (deviation from Nederwiek 1 route)
In the first part of the final section of the Nederwiek 2 cable route, between KP126.6 and KP130.35, the Boxtel Formation is mapped on the Geological map 2021[19]. According to this map Weichselian periglacial aeolian deposits of the Wierden Member subcrop in this section of the cable route trajectory. The four

[18] https://offshorewind.rvo.nl/cms/view/2dd28a50-5344-47a6-b3ff-7d0e36911159/soil-ijmuiden-ver.
[19] DINOloket.

Nederwiek 2 vibrocores that have been retrieved from this section are VC_114_C, VC_115_B, VC_116_B and VC_117_A. Non-calcareous sand that could be coherent with the Boxtel Formation have indeed been found. The vibrocore descriptions do mention admixtures of shell fragments, whole shells, organic matter and occasional mica, and the occurrences of layers, thin beds, and laminae of silty clay. These sediments could have been deposited by streams during the Late Glacial. An aeolian origin does not seem obvious, albeit that thin intercalations of wind-blown sands might be present. Late Glacial stream deposits are classified as the Singraven Member | Boxtel Formation.

From KP130.0 to KP134.5 the cable crosses a low-lying part of the seabed. The seabed elevation ranges from -35.0 mLAT to -41.1 mLAT. In this section deposits of the Early Weichselian Brown Bank Member are found at shallow depths below the seabed. These deposits consist of laminated silty clays and clayey silts with varying carbonate content and consistency. The laminae consist of very fine sand and silt and organic matter.

The GEOxyz seismic grids of Zone Site I to IV of the IJmuiden Ver Wind Farm Zone are in accordance with the seismic data that have been acquired by Next Geosolutions. The 'Base of Layered Sediments' and 'Top of Layered Sediments' grid data appear to reflect the base and the top of the Brown Bank Member, albeit that significant layers stiff silty slightly calcareous clay have been sampled above the 'Top of Layered Sediments' reflector. An example of this clay is shown in figure 12. The in this vibrocore (VC_131_C) has a rather massive character, which could account for the absence of clear parallel reflectors in the seismic profile. These clays could be part of the Early Holocene tidal clays of the Wormer Member | Naaldwijk Formation. It is also possible that these clays formed at an earlier point in time stage. For instance because of a marine inundation during Early Weichselian interstadial, such as the Odderade (85 ka – 74 ka ago). An alternative origin of the clays could be the development of a meandering river system, for instance at the end of (again) the Odderade interstadial. In the floodplain or at the riverbank clay could have been deposited.

A geo-archaeological assessment of the seismic data and vibrocore samples that have been acquired in the IJmuiden Ver Wind Farm Zone has revealed that during the Pleniglacial the channel belt of the river Rhine expanded in north-western direction over major part of Site I to IV of the wind farm zone. Possibly this channel belt crossed the Nederwiek 2 route trajectory. An indication that this could be the case is provided by the absence of layered sediments according to the Next Geosolution seismic data in a section of the cable route that lies in the extension of the channel belt. The extent of the channel belt is interpreted to be located between KP160 and KP169, but these figures shall be used as a rough estimate.

Figure 12. Clay sequence above 'Top of layered sediments' reflector

In VC_156_A and VC_157_A beds of peat have been found around -32.50 m and -33.05 mLAT. These peat beds are covered with organic clay with shell remains and juvenile shell. The peat bed is interpreted as the Early Holocene Basal Peat | Nieuwkoop formation and the organic clay as the Velsen Bed | Wormer Member | Naaldwijk Formation. The Basal Peat Bed is the transition from the underlying Pleistocene landscape the overlying Holocene sequence.

Nederwiek 2 section KP169.6 – KP203.92 (Nederwiek 2 platform)

According to 2007 TNO Top Pleistocene grid data the top of the Pleistocene sequence is located at 10 m or more in this part of the Nederwiek 2 route. The vibrocores collected predominantly contain sand. The sandy deposits are layered with alternations of slightly calcareous and very calcareous sand. Based on the descriptions and photographs it is not possible to determine whether the sands that are contained in the vibrocores are of Holocene age, as is to be expected based on the TNO Top Pleistocene grid data. However, the results geo-archaeological research carried out for the IJmuiden Ver I to IV wind farm zones indicate that deposits that in the past were labelled as the Holocene Naaldwijk Formation consist of Pleistocene deposits including the Eem Formation, the Kreftenheye Formation, and the Boxtel Formation.
Part of the layered sands that are found in the vibrocores could for instance consist of shallow marine deposits of the Brown Bank Member that were deposited during the Early Weichselian Brørup and/or Odderade *interstadials*. The subbottom profiler data show a continuous weak reflective layered facies with local truncations. Figure 13 below shows the layered facies observed near the Nederwiek 2 platform location. The shallow depth at which the layered sequence occurs at this location does not seem to match the 'Top of layered sediments' grid data provided by Next Geosolutions. The character of the seismic facies does seem to rule out the presence of rivier deposits of the Kreftenheye Formation in this part of the trajectory.

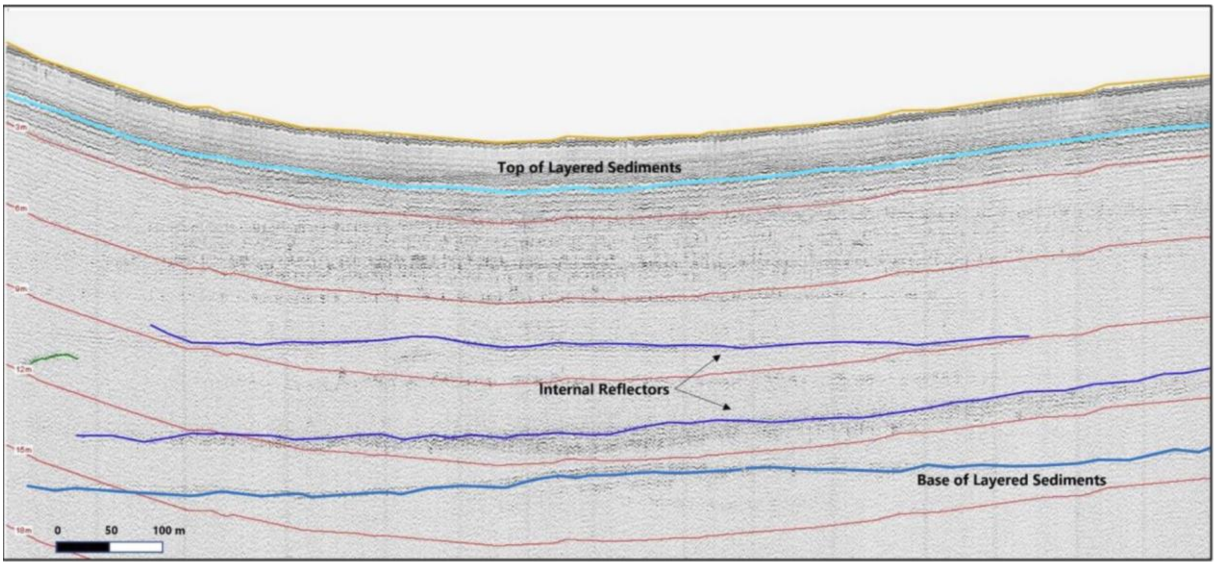

Figure 13. Next Geosolutions Survey report Figure 8-58 - SBP results from NW2 KP 199.6 to NW2 KP 202.5

4 Synthesis

For this investigation different research questions are defined in the Program of Requirements[20]. Based on the results of de data analysis the research questions are answered.

Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

Yes. There are 14 official reports of archaeological finds within the surveyed area:

NCN	RCE	Description	Found
24	46661	On this location we are dealing with certainty with a wreck which is not of archaeological interest.	Yes
192	52726	Unidentified shipwreck. Geul van de Banjaard 3	Yes
192	4918720100	Possible dingy or skiff. Geul van de Banjaard 3	Yes
193	46848	Unidentified shipwreck, Hondengat 1, sunk in 1893	No
364	46668	Unidentified wreck of a steam vessel	Yes
382	48566	Unidentified wreck of a three-masted sailing vessel	Yes
1211	4030724100	NCN 1211, no further description given	Yes
2081	4028335100	Wreck of the Anne Graebe, no further description given	Yes
2869	4905760100	Wreck, possible wooden remains, shape somewhat recognizable	Yes
9160	46488	Ceramics, Roman pottery	No
9316	48498	Unidentified wooden steam vessel with cargo iron ingots	Yes
9317	48499	Unidentified wreck of a sailing vessel, 18th or 19th century	No
9339	49358	Steam vessel SS Rival	Yes
20097	4022398100	Various finds from Roman period in sand nourishment, originating from the Hompels	No

Table 13. Official archaeological findings within the surveyed area

<u>With respect to side scan sonar, magnetometer and multibeam survey:</u>

Are there any phenomena visible on the seabed?

Yes. A total of 14231 contacts have been mapped at the seabed surface with *side scan sonar* and *multibeam*. In addition, 12663 magnetic anomalies have been mapped.

Do these phenomena have a man-made or natural origin?

Next Geosolutions has identified 14231 *side scan sonar* contacts within the survey area. The classification is listed in the table below.

Classification	Survey area		Total
	Alpha, Beta Gamma	NW1&2	
Buoy Anchor	27	-	27
Buoy	3	1	4
Benthic Mud and Detritus	632	-	632
Exposed cable	6	-	6
Debris Anchor	-	5	5

[20] Van den Brenk and van Lil, 2022.

Classification	Survey area		Total
	Alpha, Beta Gamma	NW1&2	
Debris Cable	181	2	183
Debris Fish Net	5	1	6
Debris Linear	694	90	784
Debris Metallic	54	1	55
Debris Other	4045	503	4548
Debris Wire	27	17	44
Natural Feature	5701	2162	7863
Other	3	15	18
Pipeline	13	4	17
Seabed disturbance	16	-	16
Wreck	19	4	23
Total	**10758**	**4**	**14231**

Table 14. Classification of the side scan sonar contacts

A total of 12663 magnetic anomalies have been observed within the area of investigation. 11059 anomalies cannot be related to known pipelines and cables, probable cables marked by aligning anomalies or visible objects at the seabed surface. These anomalies are related to unknown ferrous objects buried in the seabed, covered by sediments.

If these phenomena can be designated to be man-made: What classification can be attached?
The man-made phenomena include shipwrecks, lost, or dumped debris, cables, and pipelines.

If these phenomena can be classified as archaeological: *Is it possible to interpret the nature of the archaeological objects?*

A total of 53 contacts are classified as objects with a medium (25) to high (28) archaeological expectation. Contacts with a high expectation are clear larger ship wrecks or wreck remains. Contacts with a medium expectation are smaller possible wreck remains or small wrecks which are probably recent.

Besides visible object at the seabed surface, magnetic anomalies have been observed caused by buried objects which cannot be related to known objects like pipelines or cables. 87 of the magnetic anomalies related to unknown (buried) objects have peak-to-peak values of 500 nT or more. Those 87 anomalies are considered to be of potential archaeological interest.

If these phenomena can be identified as natural: What is the nature of these natural phenomena?

The phenomena interpreted as natural features are probably lumps of peat or clay.

Based on the acoustic image is it possible to designate zones of high, middle or low activity on the seabed?

Along the routes sand waves have been mapped which are known to migrate a few meters per year northwards. Sand ripples originated by tidal currents are present along the entire route.

What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?

Larger objects like the shipwrecks show scouring but are largely embedded in the seabed sediments. This appears to be the case throughout the area. Therefore, it is not possible to mark risk-prone areas selectively.

If no acoustic phenomena can be observed: Are there any clues that this is a consequence of either natural erosion, sedimentation, or human interference?

This question is given the results of the investigation not applicable.

With respect to subbottom profiler- and sampling:

Based on seismic profiles and geotechnical data is it possible to map the Pleistocene landscape?

The acquired and processed seismic data and collected vibrocore samples are of high quality. The assessment of the seismic data has been carried out through the correlation of these data (grids and figures contained in the survey report) with available geological and seismic sources.

It is not possible to map the top of the Pleistocene landscape along the full extent of the cable route. The main reasons are the following:

- The transition between the top of the Pleistocene landscape to the overlying Holocene deposits is very gradual. A seismic reflector occurs when a sudden change acoustic impedance occurs[21]. This is not the case when the layer boundary is very gradual, because of which this layer boundary is not observed as a clear reflector in the seismic profile.
- The sediments at the top of the Pleistocene and base of the Holocene sequence are the same. Also, in this case there is no difference in acoustic impedance and therefore no reflector.
- The top of the Pleistocene landscape is located below the depth of penetration of the subbottom profiler. Because the cables are installed a few meters below the seabed, a seismic profile of the top layers suffices. The subbottom profiler system is chosen to meet this demand.
- The top of the Pleistocene landscape is visible as a reflector in the seismic profile, but due to a lack of geological information, this reflector cannot simply be interpreted as being the top of the Pleistocene landscape.

Examples of locations where it proved possible to pinpoint the top of the Pleistocene landscape are:

- the locations where the silty clays of the Early Weichselian Brown Bank Member | Eem Formation were found directly underneath the mobile sands of the Bligh Bank Member | Southern Bight Formation, such as in the deeper parts (= around -40 mLAT) of the Brown Bank area, and
- the locations where the Basal Peat Bed was encountered, such as VC_156_A and VC_157_A.

In the Nederwiek 2 cable route section between KP165 and KP203.92 the geological constellation including the depth at which Pleistocene deposits are covered by Holocene deposits is uncertain.

What is the depth of the Pleistocene landscapes with respect to the present seabed?

[21] Acoustic impedance = density of the sediment * velocity with which a sound wave propagates through the sediment.

The top of the Pleistocene sequence is found at depths varying from 0.0 m to more than 10 m below the seabed. The exact depth of the deepest occurrences is not known.

From Pleistocene to Holocene deposits is the transition gradual or instantaneous (erosive)?

The transition from Pleistocene to Holocene deposits is not clearly mapped. This is due to various reasons. The first is related to the chosen geophysical method and used equipment. Second, it is often not possible to translate the seismic units into lithostratigraphic units, without the description and analysis of sediment samples.

River sand deposits of the Kreftenheye Formation are often directly covered and truncated by the mobile sands of the Bligh Bank Member | Southern Bight Formation. In the northern part/end section of the cable route the Early Pleniglacial Rhine sands grade upward into Late Glacial small scale fluvial deposits of the Singraven Member | Boxtel Formation and/or Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation. The Singraven and Wormer channels also eroded the Kreftenheye sands. In the floodplain of the Singraven streams and salt marshes related to the tidal landscape clays and peat could have been deposited imparting little erosion.

The Brown Bank Member has been identified in the seismic data as from the point where the Nederwiek 2 cable route deviates from the IJmuiden Ver (Alpha) cable route towards the Nederwiek 2 deviation point from the Nederwiek 1 cable route around KP169.6. At least part of the Brown Bank Member coincides with the seismic unit of 'Layered Sediments' that have been identified by Next GeoSolutions. The Brown Bank Member generally consists of a laminated deposits of slightly calcareous stiff silty clay and clayey silt. The laminated lagoonal and lacustrine deposits probably do not form the top the Pleistocene sequence.

In a significant section of the cable route an unknown unit is mapped, which could consist multiple lithostratigraphic units, including tidal deposits of the Naaldwijk Formation, terrestrial deposits of the Boxtel Formation, and – possibly – laminated silty clay of the Brown Bank Member. Further, the basal part of the unit which, based on available grid data, is mapped as the Bligh Bank Member, is likely to include Early Holocene tidal deposits of the Naaldwijk Formation, peat of the Basal Peat Bed | Nieuwkoop Formation and/or stream deposits of the Singraven Member | Boxtel Formation and river sand of the Kreftenheye Formation. As long as the actual lithostratigraphy of the unknown unit and the Bligh Bank Member is not resolved, it is not possible to answer this question.

Are buried channel structures observed? If so, what are the characteristics of the channel structures in terms of spatial distribution (width, depth, shape, size), the composition of the infill, stratigraphic position and age?

Yes, paleo-channels have been identified along the cable routes. The paleo-channels have incised Late Pleistocene units and are truncated by the Bligh Bank Member. The infilled channels display clear parallel layers of (what is assumed) clay, silt, and fine sand. These channels are interpreted as Early Holocene tidal channel deposits of the Wormer Member | Naaldwijk Formation and Late Glacial and Early Holocene stream deposits (clay, loam, fines sand, peat) of the Singraven Member | Boxtel Formation. Further, channel-like features are observed within the Krefteheye Formation.

Are peat/or clay deposits observed? If so: What is the spatial distribution (depth, size), stratigraphic position and age of these deposits.

Yes, layers of clay and peat have been observed at different locations along the Nederwiek 2 cable route. The vibrocores in which peat has been found are listed in the table below. Laminae, thin beds, and pockets that are part of predominantly silty of sandy units are not included in this list. The used abbreviations are explained below the table.

Vibrocore nr	Peat	Elevation Top m LAT	Elevation Base m LAT	Thickness m	Stratigraphy*	Age
VC_018_B	X	-28.58	-28.82	0.24	NIBA	EH
VC_087_A	X	-31.96	-32.29	0.33	NIBA	EH
VC_088_B	X	-31.94	-32.27	0.33	NIBA	EH
VC_089_A	X	-32.40	-32.65	0.25	NIBA	EH
VC_097_A	X	-35.09	-35.39	0.30	NIBA	EH
VC_098_A	X	-31.64	-31.79	0.15	NIBA	EH
VC_156_A	X	-32.45	-32.55	0.10	NIBA	EH
VC_157_A	X	-33.01	-33.06	0.05	NIBA	EH

Table 15. List of vibrocores with peat layers

*Preliminary interpretation

Abbreviations explained:
NIBA = Nieuwkoop Formation | Basal Peat Bed; peat
EH = Early Holocene

Can zones be identified where prehistoric settlement remains can be expected?

Remains of Palaeolithic and Mesolithic camp sites are to be expected at:

- the beaches of lagunes and at the shores of lakes (Brown Bank Member; Middle Palaeolithic)
- braided river valley (Kreftenheye Formation; Middle and Late Palaeolithic)
- river dunes (Boxtel Formation; Late Palaeolithic and Mesolithic)
- cover sand dunes and ridges (Wierden Member | Boxtel Formation; Late Palaeolithic and Mesolithic)
- the valleys of small streams (Singraven Member | Boxtel Formation; Late Palaeolithic and Mesolithic)

It is not possible to designate areas where the Pleistocene landscape and Early Holocene landscapes and related archaeological remains have been preserved intact and identify zones where prehistoric settlements are to be expected. In general can be said, that areas that did not suffer from erosion due to later sedimentation could contain intact remains. Often these areas are parts of the landscape that have been covered with peat or clay, which protected landscape and remains in the context of this landscape against erosion. From this research it has become apparent that there are some major question marks regarding the lithostratigraphy along the Nederwiek 2 cable route. These question marks primarily concern the base of the Bligh Bank Member and the actual age and genesis of an unknown unit that most likely has been deposited in the Late Glacial and Early Holocene and lies in between the top of the Pleistocene units and the overlying Bligh Bank Member.

If so:

Could these expected settlement remains be affected by the installation of the cables based on their vertical position related to the seabed?

Yes, settlements could be affected by the installation of cables if:

- the favourable elements of the paleo-landscapes (dunes, stream valleys, beaches of lagoons, shores of lakes, et cetera) occur along the cable route, and
- these paleo-landscapes have not been affected by erosion, and
- the paleo-landscapes and related in situ prehistoric remains are located proximate to the seabed surface, within the depth range of the cable trencher.

Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?

No, these indications have not been observed. It should be noted, that with seismics only objects can be found, which are located straight beneath the subbottom profiler; buried objects located in between survey lines cannot be traced.

If so:
Based on the presence of buried objects and its correlation with side scan sonar, magnetometer and multibeam data can something be said about the nature of these buried objects?

This question is not applicable.

5 Summary and recommendations

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echo sounder* and *subbottom profiling*) recorded within the survey corridor covering a total area of 489 km^2 have been analysed in order to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second and step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Within the surveyed area, an archaeological expectation was assigned to a total of 53 contacts. In accordance with the directive from the Cultural Heritage Agency of the Netherlands (RCE), = no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). These side scan sonar contacts are considered to be of archaeological value until it is proven not to be through a visual assessment done by a certified archaeologist.

Along the Nederwiek 2 route 2 of the sonar contacts fall within 100 meters of the route.

ID	E	N	Distance to the cable(m)
SSS_GVA_01403	536762	5807461	64
SSS_COB_02273	525796	5907245	37

Table 16. Potential archaeological contacts within 100 meters from route Nederwiek 2

Magnetic anomalies

At 87 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Along the Nederwiek 2 route 9 of the magnetometer contacts fall within 100 meters of the route.

Anom_ID	Amplitude	Easting	Northing	Distance to the cable(m)
MAG_BEA_0066	919.2	567692	5752519	50
MAG_BEA_0082	1238.4	567622	5752445	75
MAG_LOC_410012	612.6	555549	5751212	66
MAG_COB_00535	559.5	536761	5803815	3
MAG_COB_00488	560.9	536831	5803830	74
MAG_COB_01114	3511.3	516294	5860969	1
MAG_BRK_60678	2669.7	515268	5866394	3
MAG_BRK_60946	2471.6	523727	5898339	5
MAG_COB_02590	571.1	523781	5898359	62

Table 17. Potential archaeological magnetometer contacts within 100 meters from route Nederwiek 2

In accordance with the directive from the Cultural Heritage Agency of the Netherlands (RCE), no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). These magnetometer contacts are considered to be of archaeological value until it is proven not to be through a visual assessment done by a certified archaeologist. All locations of potential archaeological interest are shown in figure 14.

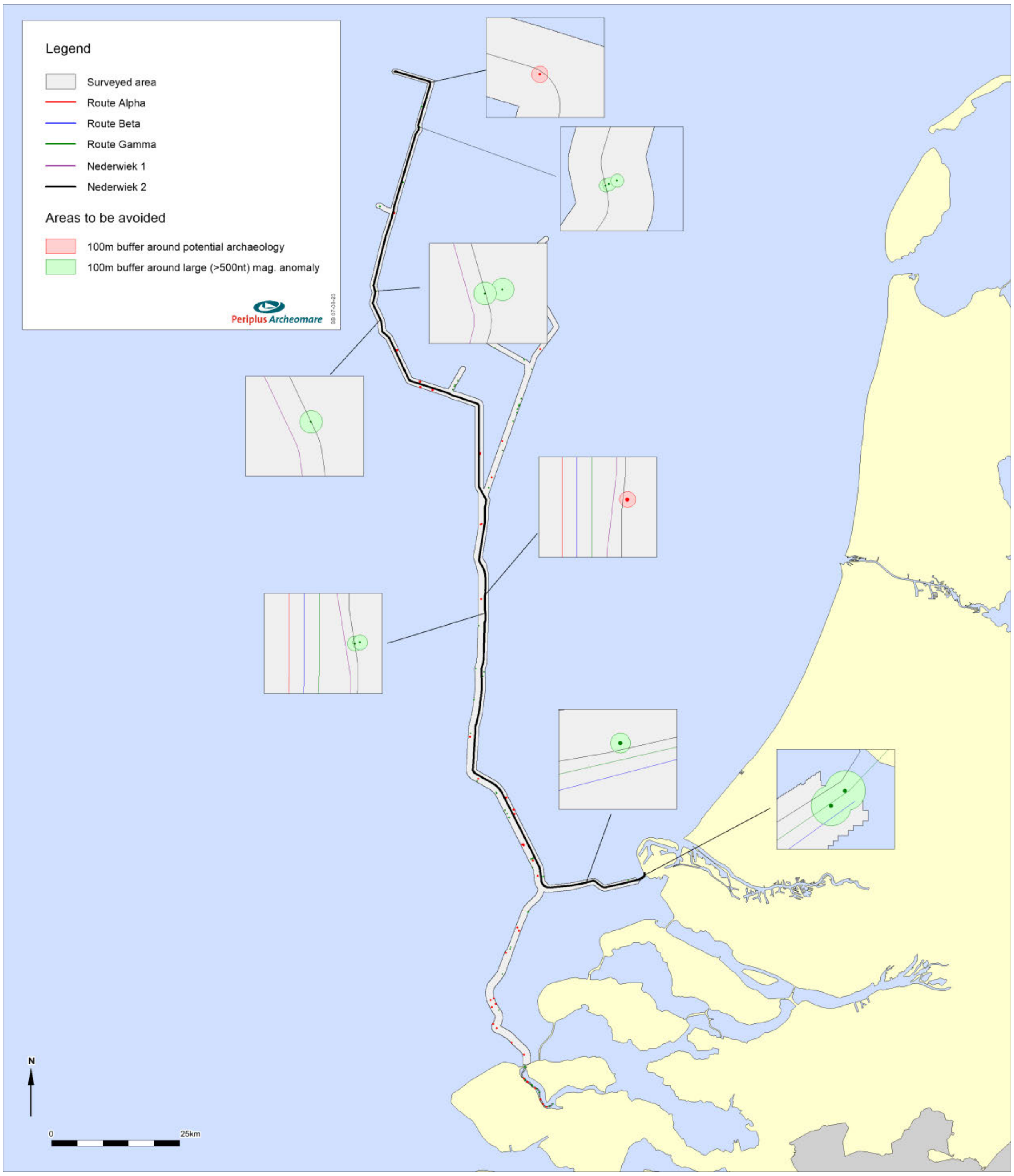

Figure 14. Advice - Sites to be avoided along the Nederwiek 2 route including a 100-meter buffer zone.

The buffer zone of 100 meters is a standard that applies to the protection of cultural heritage.. However, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Reduction of the distance has to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the enforcing authority, acting on behalf of the Ministry of Economic Affairs and Climate Policy. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported *magnetometer* locations, additional research is required in order to determine the actual archaeological value of the reported locations. It is advised that the UXO research within 100 meters of the *magnetometer* anomalies are carried out under archaeological supervision. Depending on the outcome of the UXO research it can be decided if additional research (for instance by means of ROV or dive investigations) is needed. If the UXO research indicates that the object has no archaeological value, the location can be omitted.

Prehistoric landscapes and related archaeological remains

The assessment of seismic data, vibrocore descriptions and CPT-logs has shown that an intact well-preserved sequence of Late Pleistocene and Early Holocene landscapes could locally have been preserved along the cable route. It is not possible to specifically target the areas where the Pleistocene landscape is intact. Therefore, it cannot be excluded that in part of the trajectory intact well-preserved prehistoric landscapes and possible archaeological remains contained herein are affected by the installation of the cables. However, due to small size of Late Paleolithic and Mesolithic camp sites it is very difficult to trace and map these sites. Generally, these campsites do not exceed a few m^2. Therefore, it is not possible to take mitigating measures to prevent disturbance of sites.

The analysis of vibrocore samples offers an opportunity to gain valuable information on the development of Late Pleistocene and Early Holocene terrestrial and aquatic landscapes which are crossed by the cables. It is advised to conduct specialist research including AMS ^{14}C age dating, pollen, diatom, it is advised to conduct specialist research including AMS ^{14}C age dating, pollen, diatom, foraminifera, and ostracod analysis. The designation of vibrocores and sample intervals shall, in accordance with the Dutch Quality Standard (Dutch: Kwaliteitsnorm Nederlandse Archeologie) be documented in a Plan of Action. It is suggested to focus on a limited number of representative vibrocores, from which a large number of intervals are sampled, instead of selecting a large number of vibrocores from which a small number of samples are taken.

During the installation of the cables, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend archaeological supervision based on an approved Program of Requirements. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Rijkswaterstaat). This notification must also be included in the scope of work.

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Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage
CPT	Cone penetration test
Eemian	Warm period (interglacial) between Saalian and Weichselian from 130.000 to 115.000 years ago
Erratic	An (glacial) erratic is a piece of rock that differs from the size and type of rock native to the area in which it rests. These rocks are carried by glacial ice, often over distances of hundreds of kilometres. Erratics can range in size from pebbles to large boulders.
Ferrous	Material, which is magnetic or can be magnetized, and well-known types are iron and nickel
Glacial	Ice-age
Holocene	Youngest geological epoch (from the last Ice Age, around 10,000 BC. to the present)
In situ	At the original location in the original condition
Interglacial	Warm period in between two ice-ages
KNA	Kwaliteitsnorm Nederlandse Archeologie = Dutch Quality Standard for Archaeological Research
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
Saalian	Second last Ice age (glacial) from 240.000 to 130.000 years ago
Sidescan sonar	Acoustic instrument that registers the amplitude of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil
Current ripples	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side
Subbottom profiler	Acoustic system used to create seismic profiles of the subsurface
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	Vibrocore bore is a special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place
Weichselian	Last Ice Age (glacial) from 115.000 to 12.000 years ago

References

Literature

- Busschers, F.S., C. Kasse, R.T. Van Balen, J. Vandenberghe, K.M. Cohen, H.J.T. Weerts, J. Wallinga, C. Johns, P. Cleveringa and F.P.M. Bunnik, 2007: Late Pleistocene evolution of the Rhine-Meuse system in the southern North Sea basin: imprints of climate change, sea-level oscillation and glacio-isostacy. Quaternary Science Reviews 26 (25-28), 3216-3248.
- NextGEO, 2022. OFFSHORE GRID NL - Offshore Route Survey Activities (non-UXO) IJmuiden Ver Alpha/Beta/Gamma. Final Report - Integrated Geophysical & Geotechnical Report.
- NextGEO, 2023. OFFSHORE GRID NL - Offshore Route Survey Activities (non-UXO) Nederwiek 1,2 and 3. Final Report - Integrated Geophysical & Geotechnical Report.
- Van den Brenk, S. en R. van Lil, 2021. *Inventariserend Veldonderzoek (opwaterfase), de Banjaard, Noordzee*. Periplus Archeomare rapport 20A015-03.
- Van den Brenk, S. en R. van Lil, 2021. *Programma van Eisen IJmuiden Ver Alpha*. Periplus Archeomare project 21A001-01.
- Van den Brenk, S. en R. van Lil, 2021. *Programma van Eisen IJmuiden Ver Beta*. Periplus Archeomare project 21A002-01.
- Van den Brenk, S., 2022. *Programma van Eisen IJmuiden Ver Gamma*. Periplus Archeomare project 21A002-05.
- Van Heeteren, S., 2010. Analysis of seabed and soil quality required for wind farms. We@Sea project 2005-005.
- Van Lil, R. en R.W. Cassée, 2021. *Archeologisch bureauonderzoek Net op zee IJmuiden Ver Gamma*. Periplus Archeomare rapport 21A002-04.
- Van Lil, R., S. van den Brenk en R.W. Cassée, 2021. *Archeologisch bureauonderzoek Net op zee IJmuiden Ver Alpha*. Periplus Archeomare rapport 20A024-01A.
- Van Lil, R., S. van den Brenk en R.W. Cassée, 2021. *Archeologisch bureauonderzoek Net op zee IJmuiden Ver Beta*. Periplus Archeomare rapport 20A024-01B.
- Van den Brenk, S., van Lil, R. en R.W. Cassée, 2023. *Archeologisch bureauonderzoek Net op zee Nederwiek 1*. Periplus Archeomare rapport 22A027-01.
- Van den Brenk, S., van Lil, R. en R.W. Cassée, 2023. *Archeologisch bureauonderzoek Net op zee Nederwiek 2*. Periplus Archeomare rapport 22A028-01.
- Vink, A., Steffen, H., Reinhardt, L. en Kaufmann, G., 2007. Holocene relative sea-level change, isostatic subsidence and the radial viscosity structure of the mantle of northwest Europe (Beglium, The Netherlands, Germany, southern North Sea). *Quaternary Science* Reviews, 26, pp. 3249-3275.

Sources from the Internet

- Dienst der Hydrografie (www.hydro.nl)
- Geologische Dienst Nederland – Data Informatie Nederlandse Ondergrond (www.dinoloket.nl)
- Noordzeeloket (www.noordzeeloket.nl)
- North Sea paleo-landscapes, University of Birmingham (http://www.iaa.bham.ac.uk)
- Olie en Gasportaal (www.nlog.nl)
- Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB.nl)

Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg, objectendatabase Rijkswaterstaat Noordzee en Delta

Appendix 1. Potential Archaeological sites

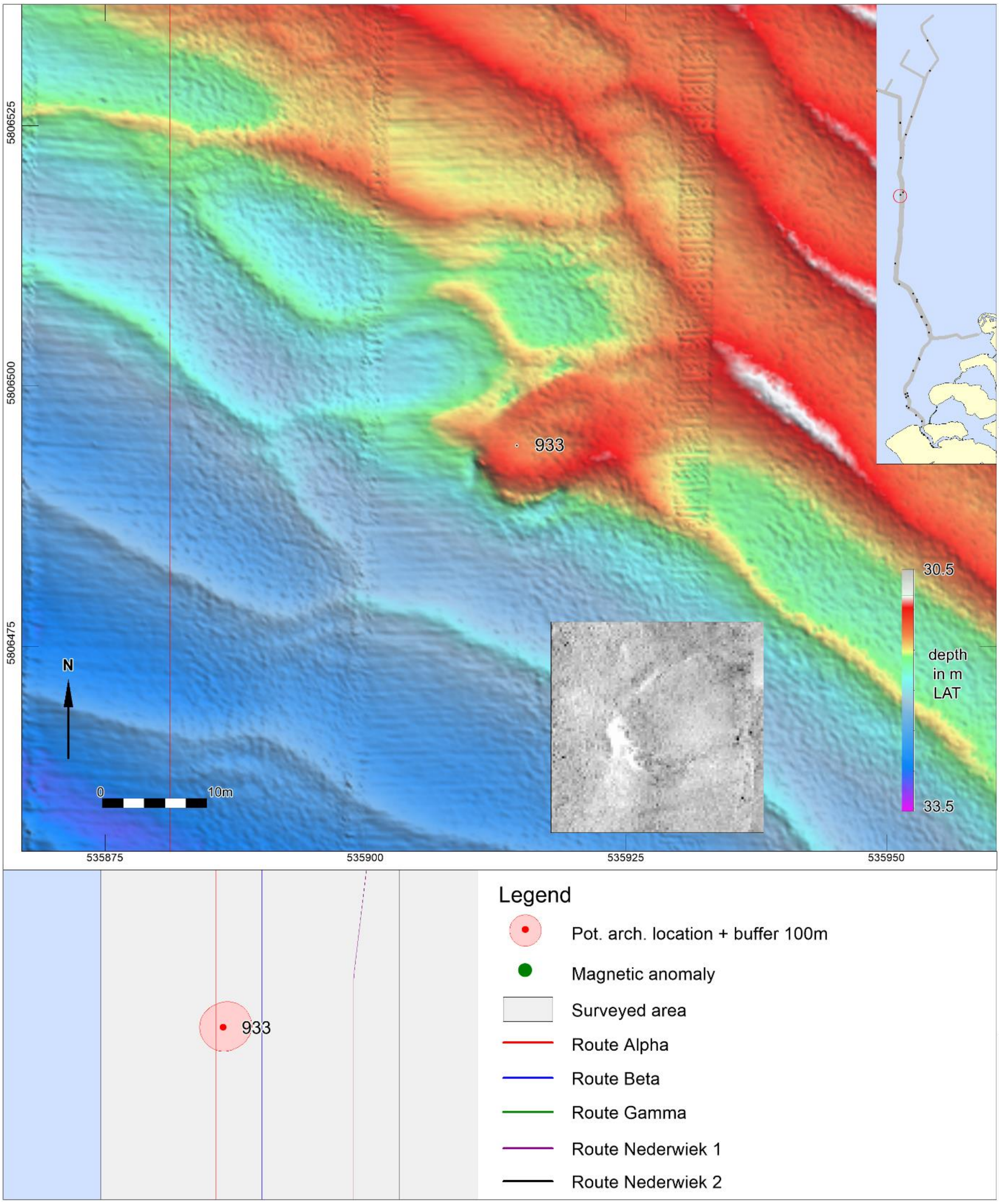
Based on side scan sonar and multibeam echo sounder recordings.

Appendix 1 – Potential archaeological sites

From surveys Net op Zee IJmuiden Ver Alpha, Beta, Gamma, Nederwiek 1, 2

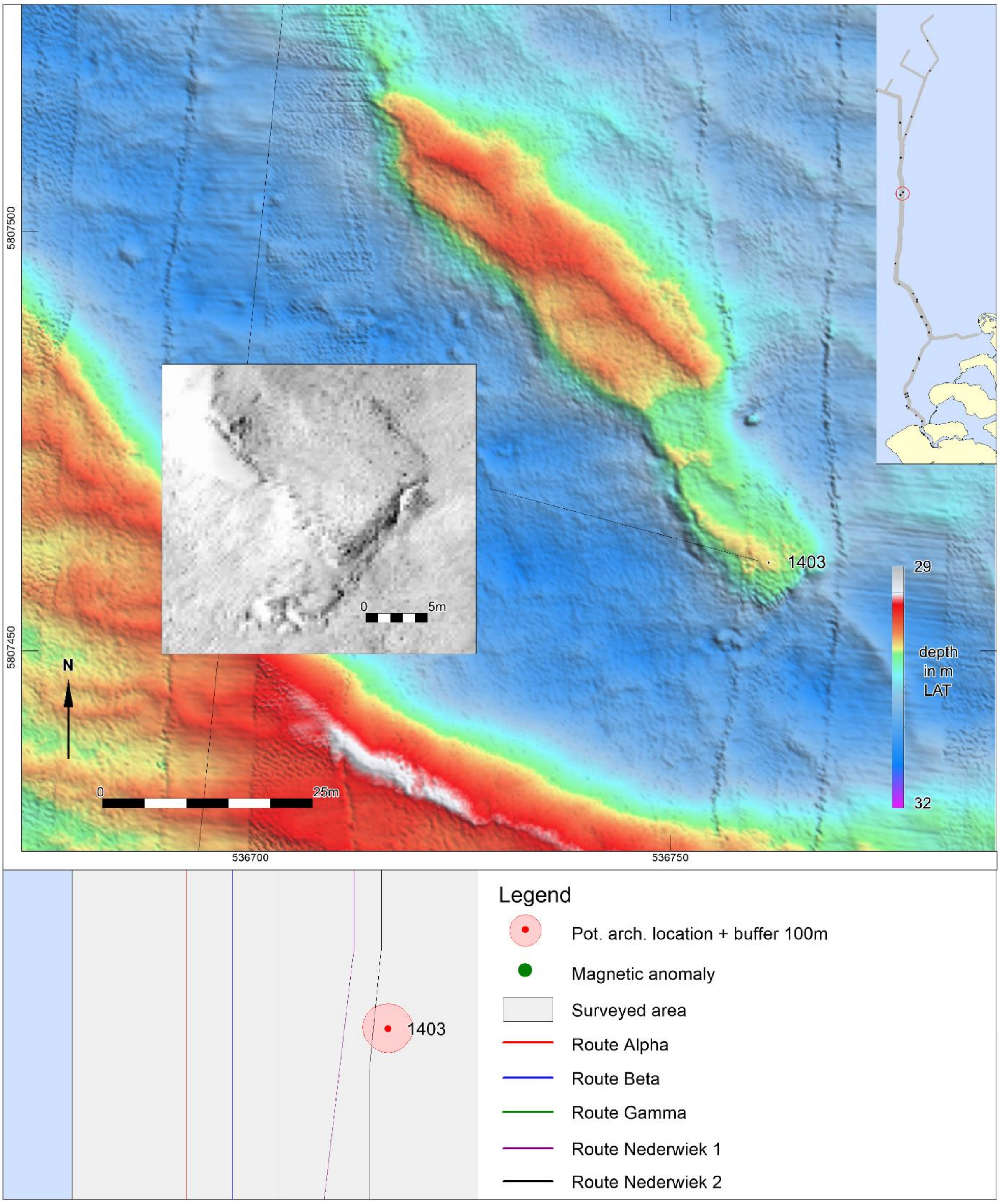
ID	Feature Next	Easting	Northing	Depth	NCN	Classification PPA
933	Debris linear	535914	5806494	-31.2	-	Possible wreck remains
1403	Debris other	536762	5807461	-30.0	13903	Possible wreck remains
1488	Wreck	533775	5779687	-29.2	2869	Wreck
1724	Debris other	535351	5771480	-28.1	-	Wreck remains
1903	Debris other	543918	5758747	-26.6	-	Wreck remains
1906	Debris other	543999	5758712	-25.3	-	Wreck remains
1933	Debris linear	544136	5758591	-27.4	-	Wreck remains
1948	Debris other	544209	5758751	-24.5	382	Wreck
1954	Wreck	544260	5758544	-25.7	-	Wreck
2060	Debris metal	546040	5755589	-23.7	-	Possible wreck remains
2298	Wreck	546976	5752572	-24.6	364	Wreck
3110	Debris other	537985	5830159	-25.8	-	Possible wreck remains
3149	Debris linear	540080	5837238	-32.0	-	Possible wreck remains
10053	Wreck	535976	5821101	-29.8	2810	Wreck
10059	Wreck	535882	5821036	-30.5	-	Possible wreck remains
10078	Debris other	535768	5834877	-27.9	-	Possible wreck remains
10083	Wreck	535656	5834718	-24.8	2081	Wreck
27085	Debris linear	540790	5737641	-22.2	-	Possible wreck remains
28022	Debris linear	543281	5741924	-24.4	-	Wreck remains
28068	Debris linear	543025	5742529	-22.1	-	Possible wreck remains
28228	Wreck	543296	5741910	-24.3	-	Wreck
40370	Wreck	548023	5708143	-15.1	-	Wreck, recent
40372	Wreck	544298	5713143	-16.3	-	Wreck, recent
40465	Wreck	544976	5712448	-9.5	-	Wreck, recent
40530	Debris linear	546499	5711248	-10.6	-	Possible wreck remains
40531	Debris linear	546471	5711261	-11.4	-	Wreck remains
40553	Debris other	548641	5707654	-8.7	-	Possible wreck remains
40812	Debris linear	545032	5712482	-8.8	-	Possible wreck remains
40817	-	544969	5712546	-9.4	-	Wreck remains
42231	Wreck	544305	5717781	-4.9	1670	Wreck
43101	Wreck	538996	5722986	-11.9	-	Wreck
43103	Wreck	541871	5720092	-13.9	-	Wreck
60125	Debris linear	547506	5709051	-13.8	-	Possible wreck remains
65017	Wreck	538034	5727082	-0.4	9339	Wreck
440161	Debris linear	538263	5723739	-10.4	-	Possible wreck remains
450041	Wreck	538796	5727655	-9.1	-	Wreck
450063	Wreck	537778	5728407	-9.0	-	Wreck
450128	Wreck	538786	5727670	-7.7	9316	Wreck
450153	Wreck	538420	5728758	-7.4	192	Wreck
2140014	Debris other	547442	5855149	-30.5	-	Possible wreck remains
2150001	Wreck	546418	5867040	-25.8	-	Possible wreck remains
2150002	Wreck	546385	5867084	-25.9	-	Possible wreck remains
BRK_11012	Debris Linear	540808	5767868	-27.7	-	Possible wreck remains
BRK_11020	Debris Other	542369	5764697	-28.5	-	Possible wreck remains
COB_00438	Debris Other	526488	5847207	-35.1	-	Possible wreck remains
COB_00461	Debris Linear	524100	5847759	-40.7	-	Possible wreck remains

ID	Feature Next	Easting	Northing	Depth	NCN	Classification PPA
COB_00463	Debris Other	524040	5848843	-40.5	-	Possible wreck remains
COB_00536	Debris Other	519571	5854937	-34.0	-	Possible wreck remains
COB_02273	Debris Fish Net	525796	5907245	-27.8	-	Possible wreck remains
BRK_11019	Wreck	542324	5765516	-25.1	24	Wreck
COB_00642	Wreck	518981	5881679	-27.7	1211	Wreck
COB_00655	Wreck	518956	5881687	-27.2	1211	Wreck
COB_00654	Wreck	518972	5881684	-27.2	1211	Wreck



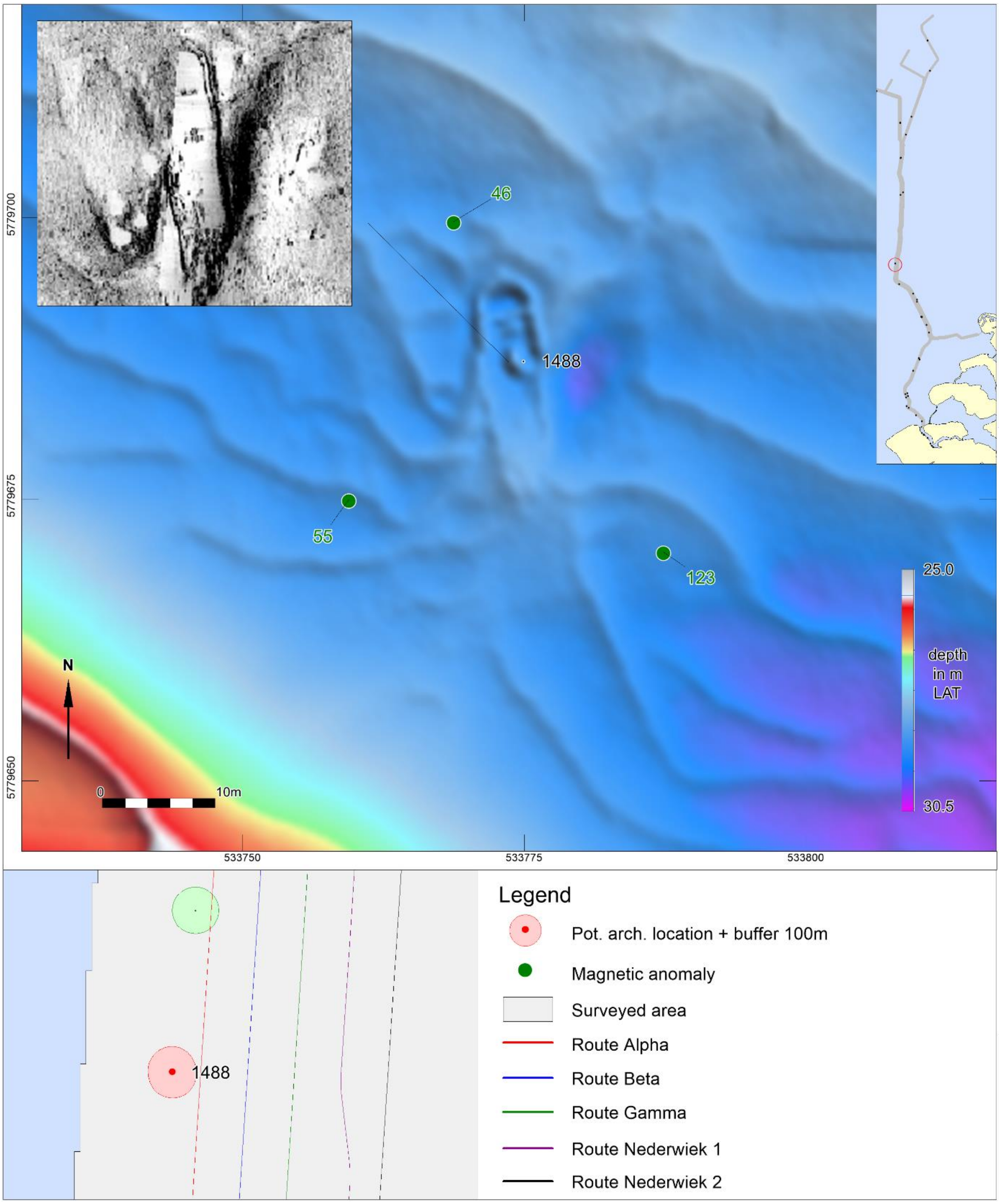
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
933	Debris linear	23.6	9.8	0.2	535914	5806494	-31.2	114.206

NCN	Description PPA	Classification PPA	Class
-	Oval structure 25x10m, no mag. possible wreck	Possible wreck remains	1



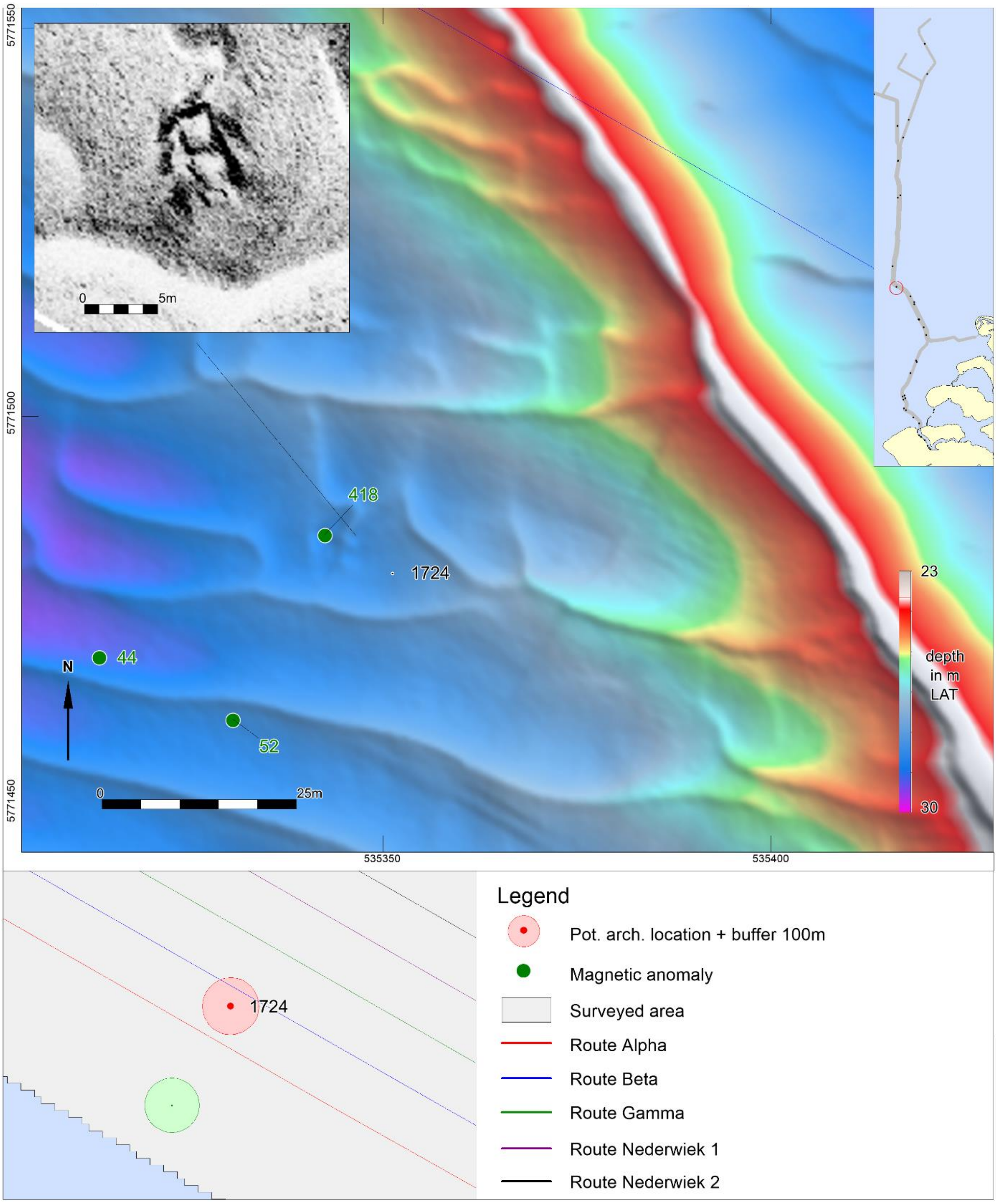
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
1403	Debris other	25.6	2.3	0.7	536762	5807461	-30.0

NCN	Description PPA	Classification PPA	Class
13903	Cluster of small objects in rectangular structure	Possible wreck remains	1



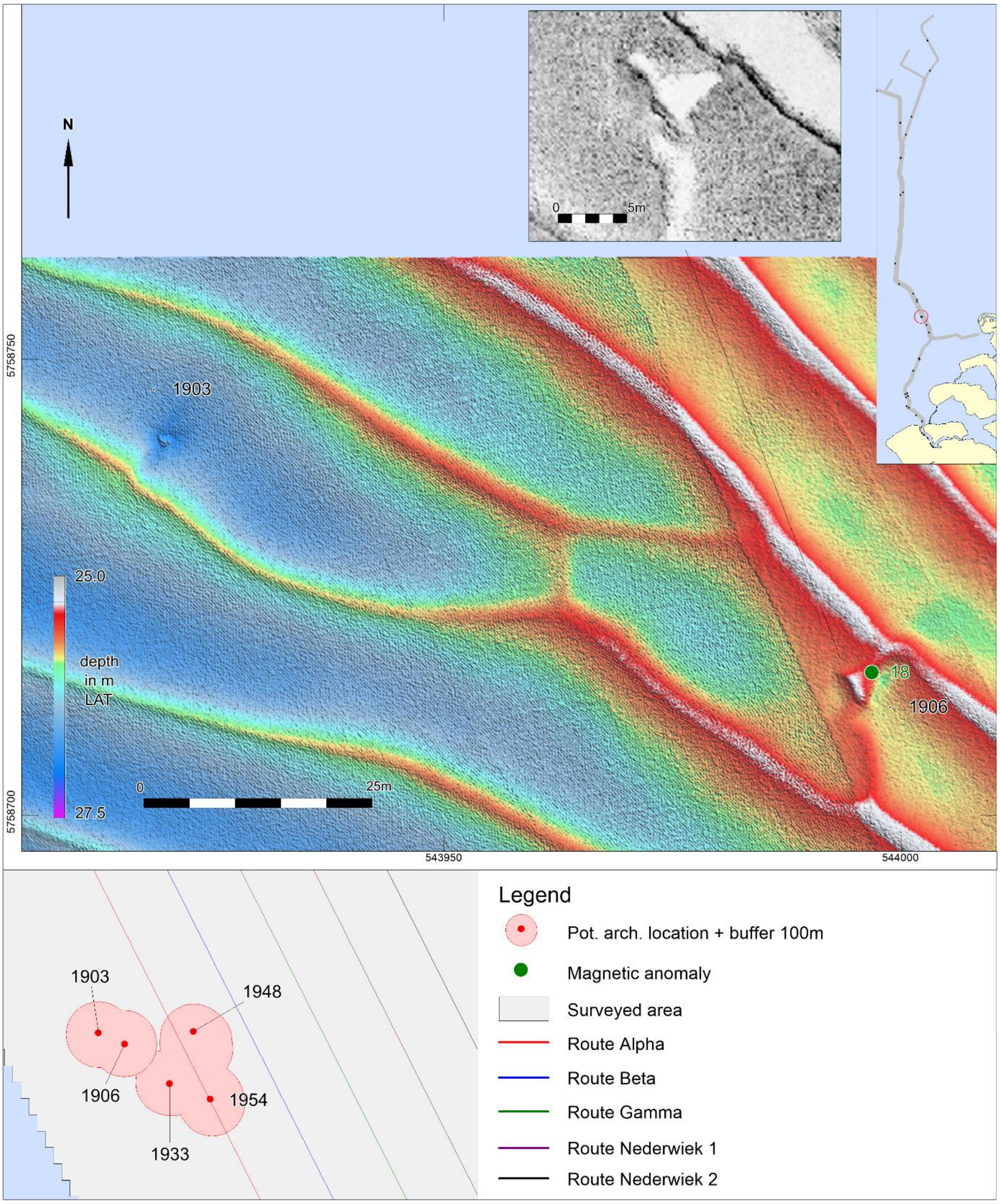
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
1488	Wreck	24.3	5.9	0.4	533775	5779687	-29.2

NCN	Description PPA	Classification PPA	Class
2869	Unidentified wreck, wood. NCN 2869	Wreck	2



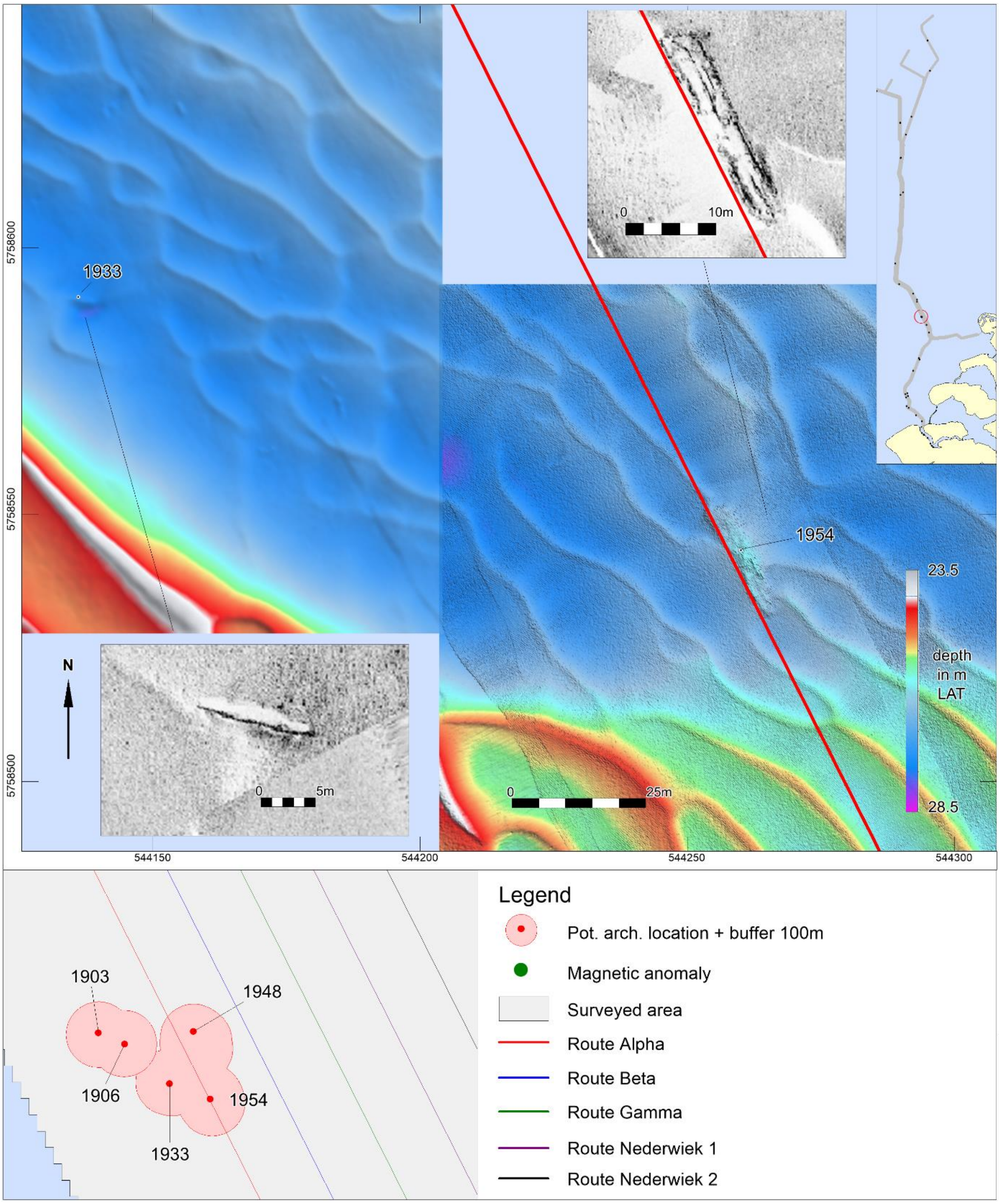
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Beta
1724	Debris other	4.8	3.3	0.4	535351	5771480	-28.1	46.319

NCN	Description PPA	Classification PPA	Class
-	Cluster of square objects with strong reflection	Wreck remains	1



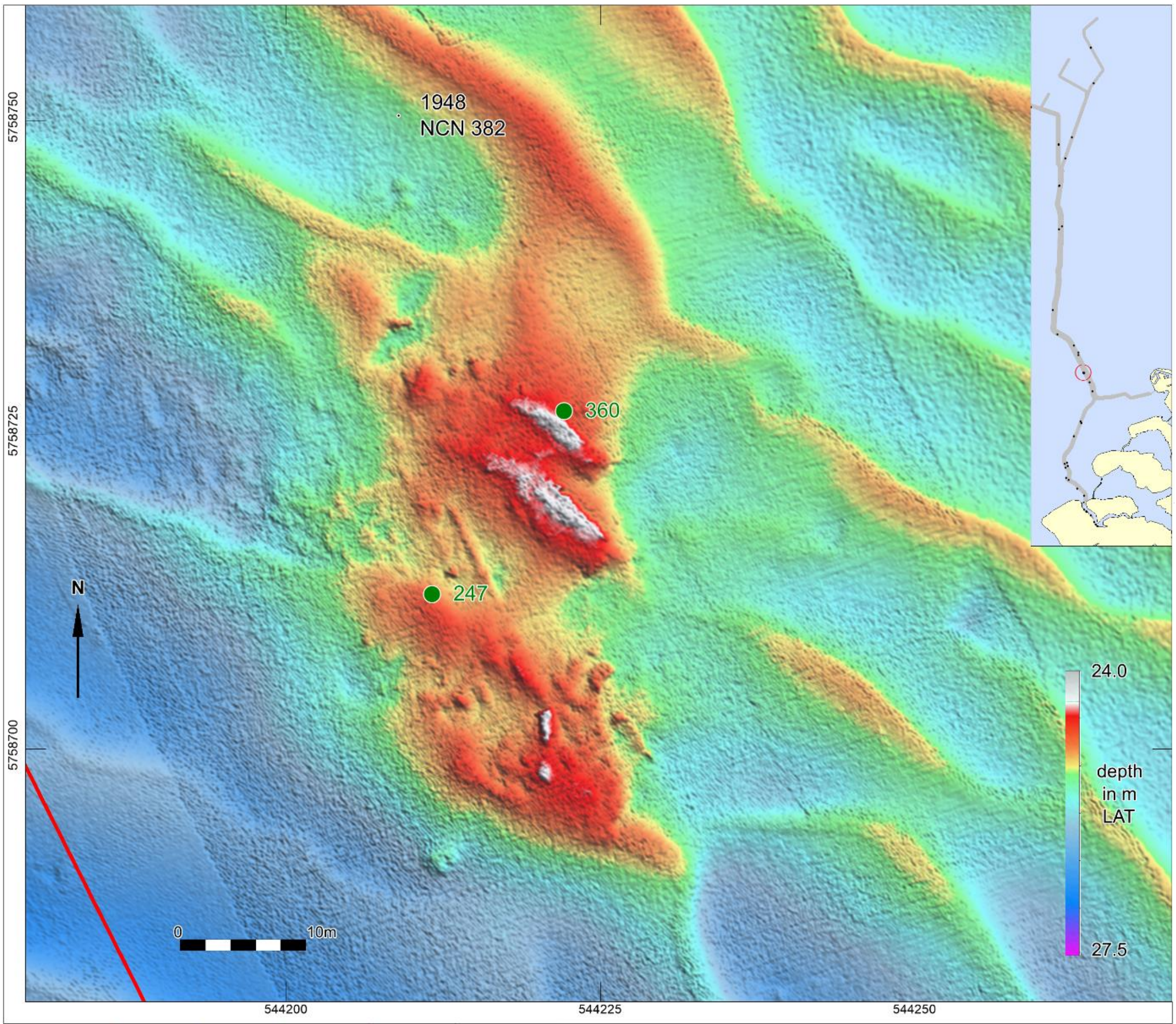
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
1903	Debris other	3.1	1.3	0.4	543918	5758747	-26.6
1906	Debris other	7.1	1.1	0.8	543999	5758712	-25.3

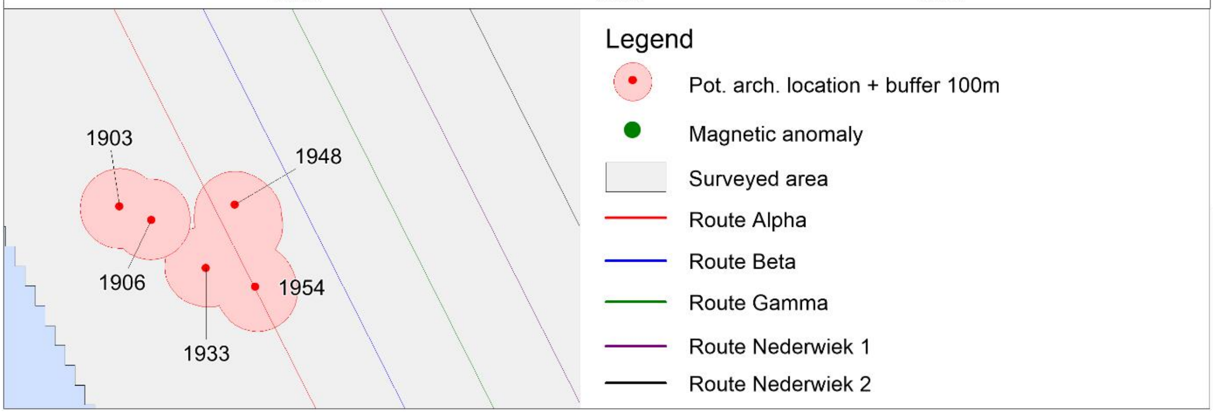
NCN	Description PPA	Classification PPA	Class
-	Partly buried structure 2 x 2 m 250m w of wreck NCN 382	Wreck remains	2
-	Rectangular isolated object 3.8 x 1.3 m, 200m w of wreck NCN 382	Wreck remains	2



ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
1933	Debris linear	10.9	0.4	0.2	544136	5758591	-27.4	62.038
1954	Wreck	23.8	5.1	0.8	544260	5758544	-25.7	61.940

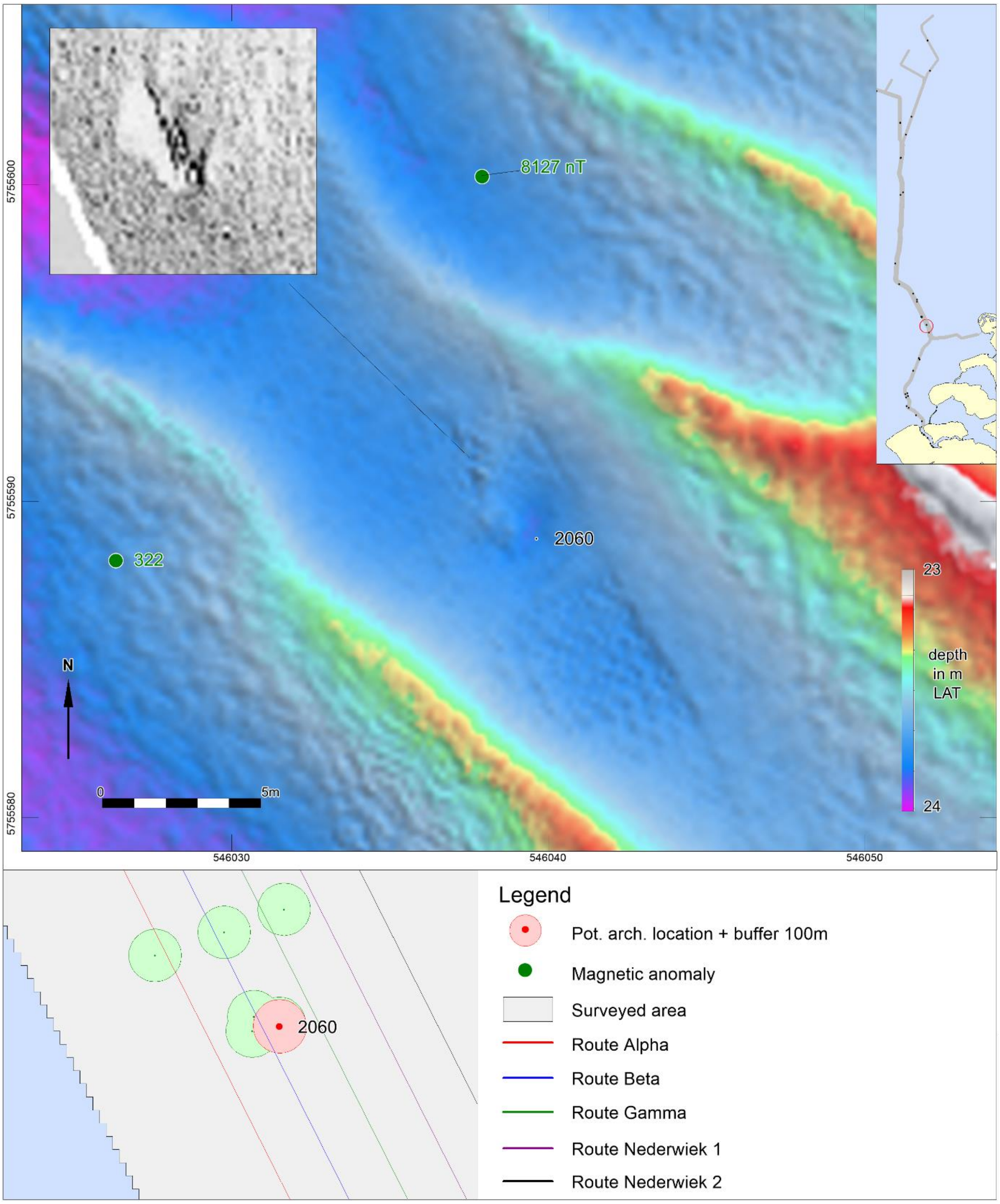
NCN	Description PPA	Classification PPA	Class
-	Partly buried structure w of wreck remains NCN 382	Wreck remains	2
-	Large structure 23 x 4m, probably wreck	Wreck	2





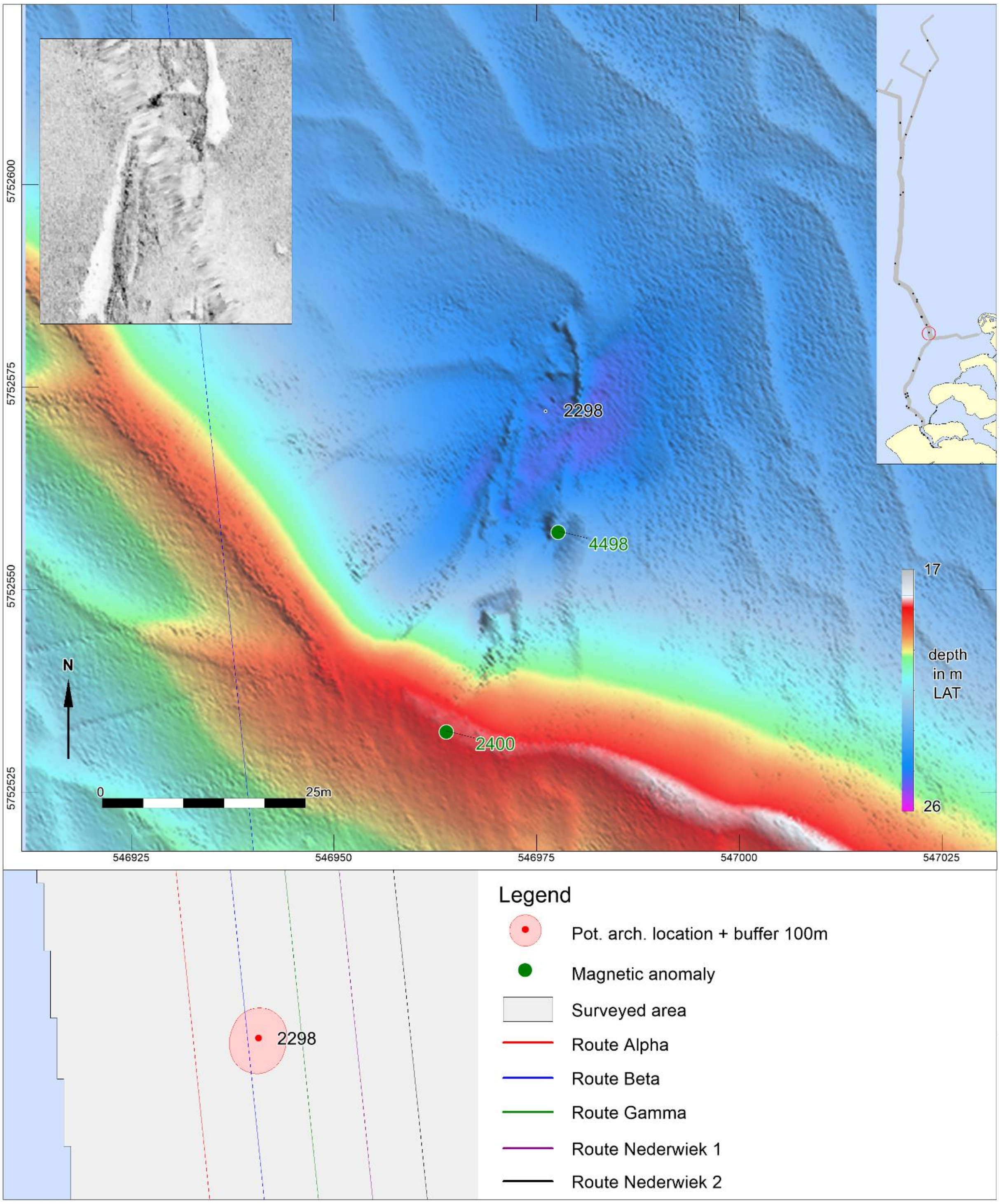
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
1948	Debris other	4.3	1.4	0.2	544209	5758751	-24.5	62.148

NCN	Description PPA	Classification PPA	Class
382	Wreck remains NCN 382, wooden sailing vessel, three-masted reported by divers. RCE 3035875100	Wreck	2



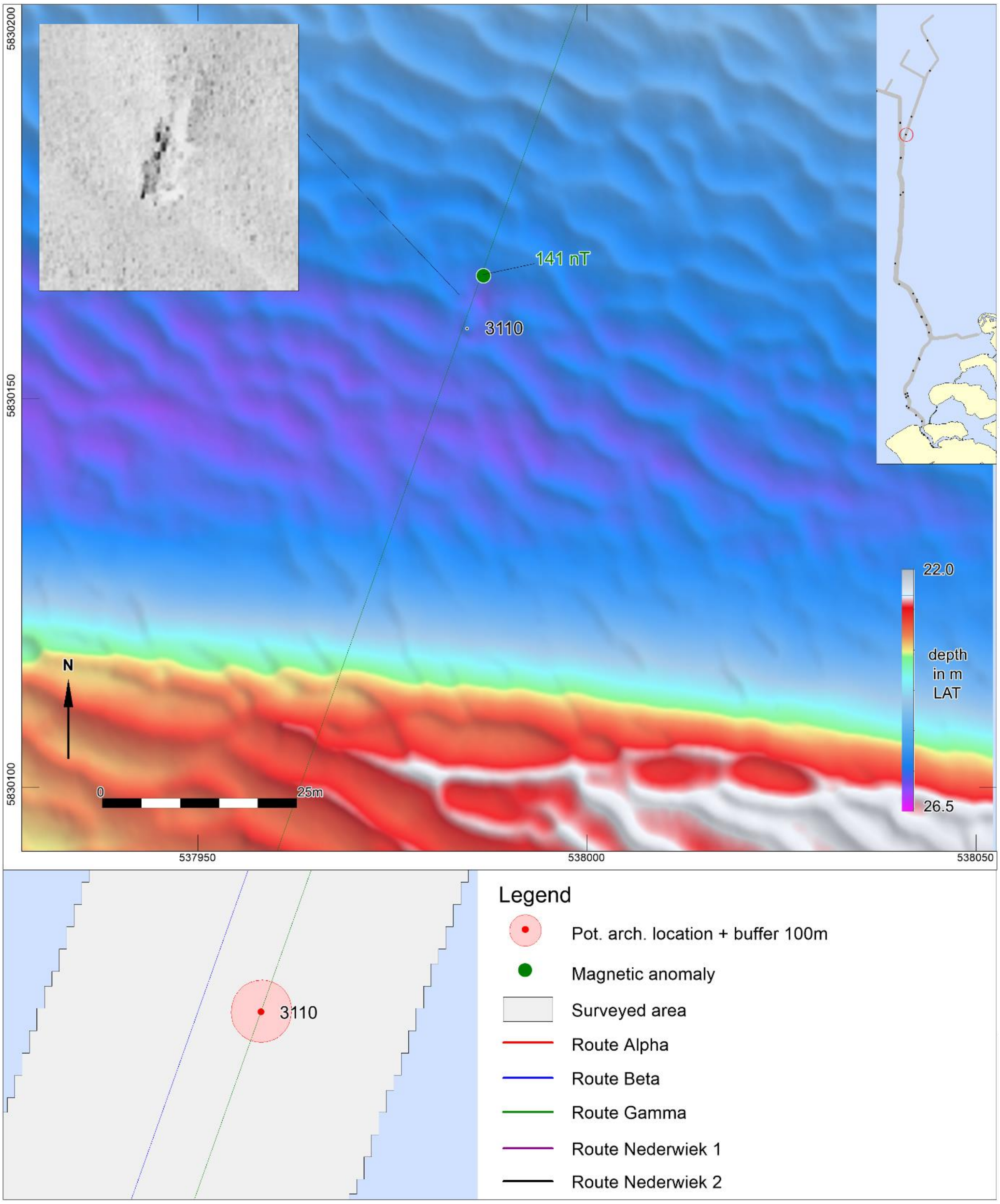
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Beta
2060	Debris metal	4.2	1.6	0.2	546040	5755589	-23.7	26.670

NCN	Description PPA	Classification PPA	Class
-	Cluster of small objects, large Mag. 8127 nT	Possible wreck remains	1



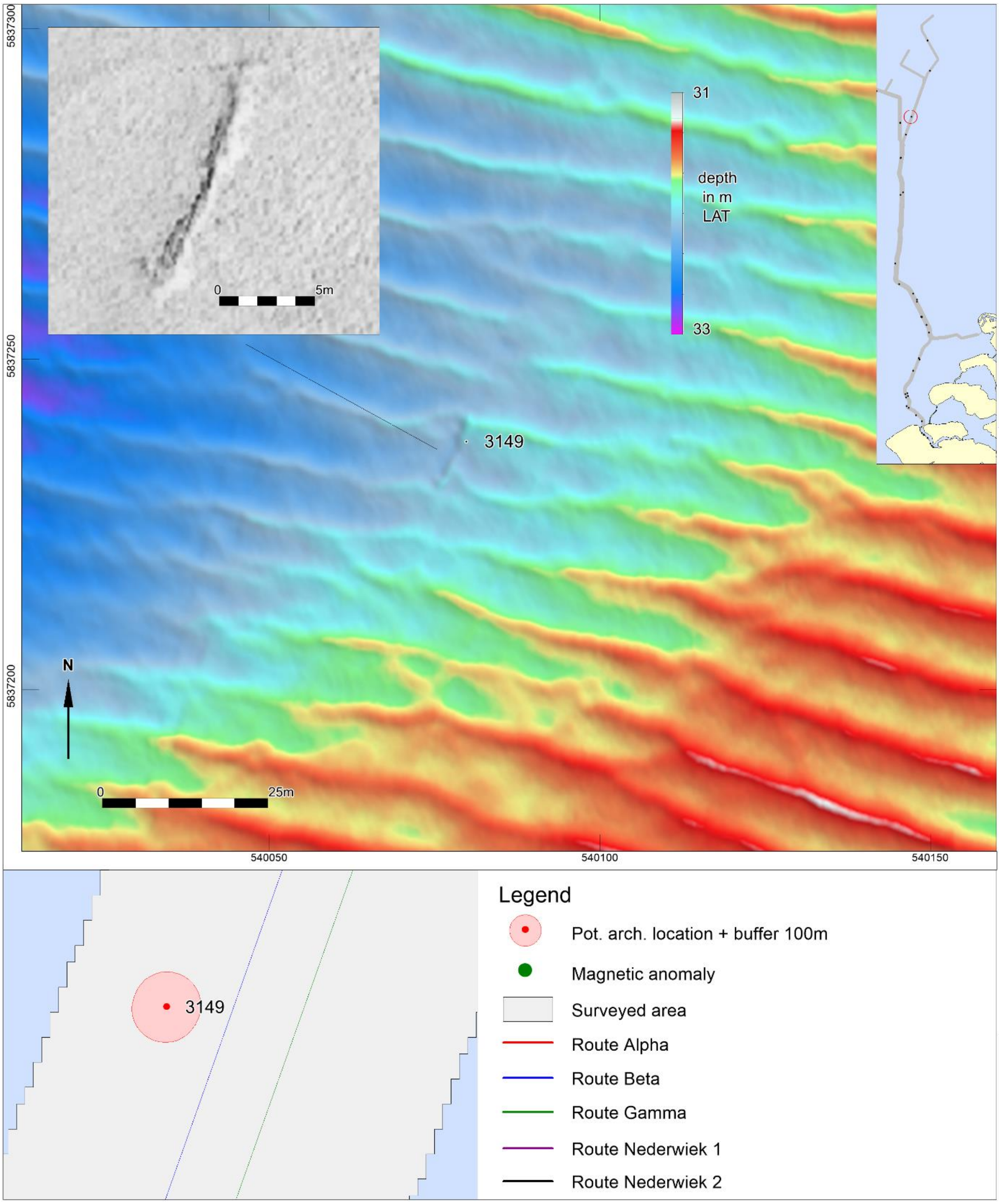
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Beta
2298	Wreck	46	8.4	4.3	546976	5752572	-24.6	23.485

NCN	Description PPA	Classification PPA	Class
364	Wreck NCN 364, large MAG anomalies. Wreck of a large steam vessel, iron rudder. RCE 2966920100	Wreck	2



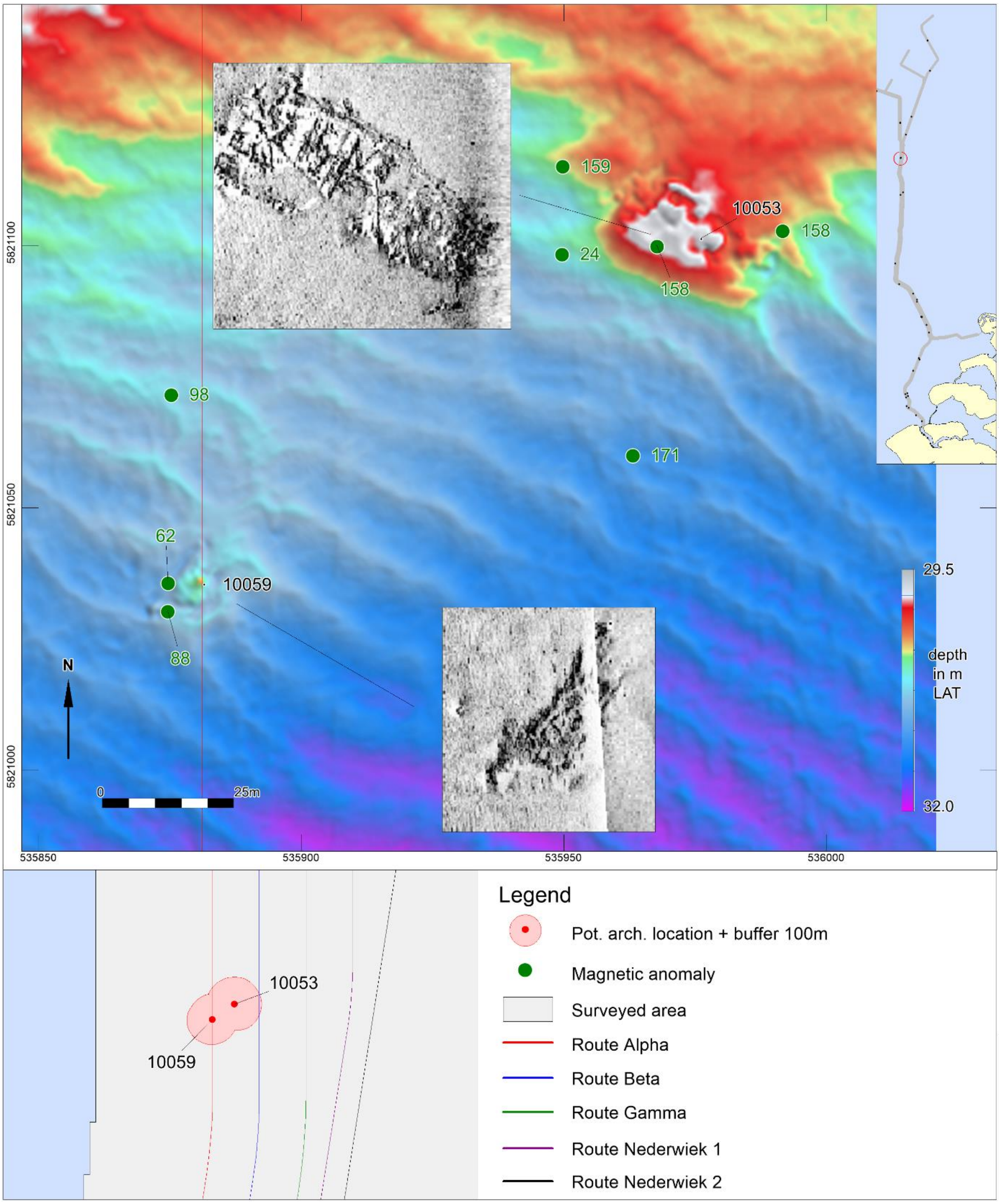
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Gamma
3110	Debris other	6.9	1.2	0.2	537985	5830159	-25.8	106.046

NCN	Description PPA	Classification PPA	Class
-	Rectangular structure. Mag anomaly 141 nT	Possible wreck remains	1



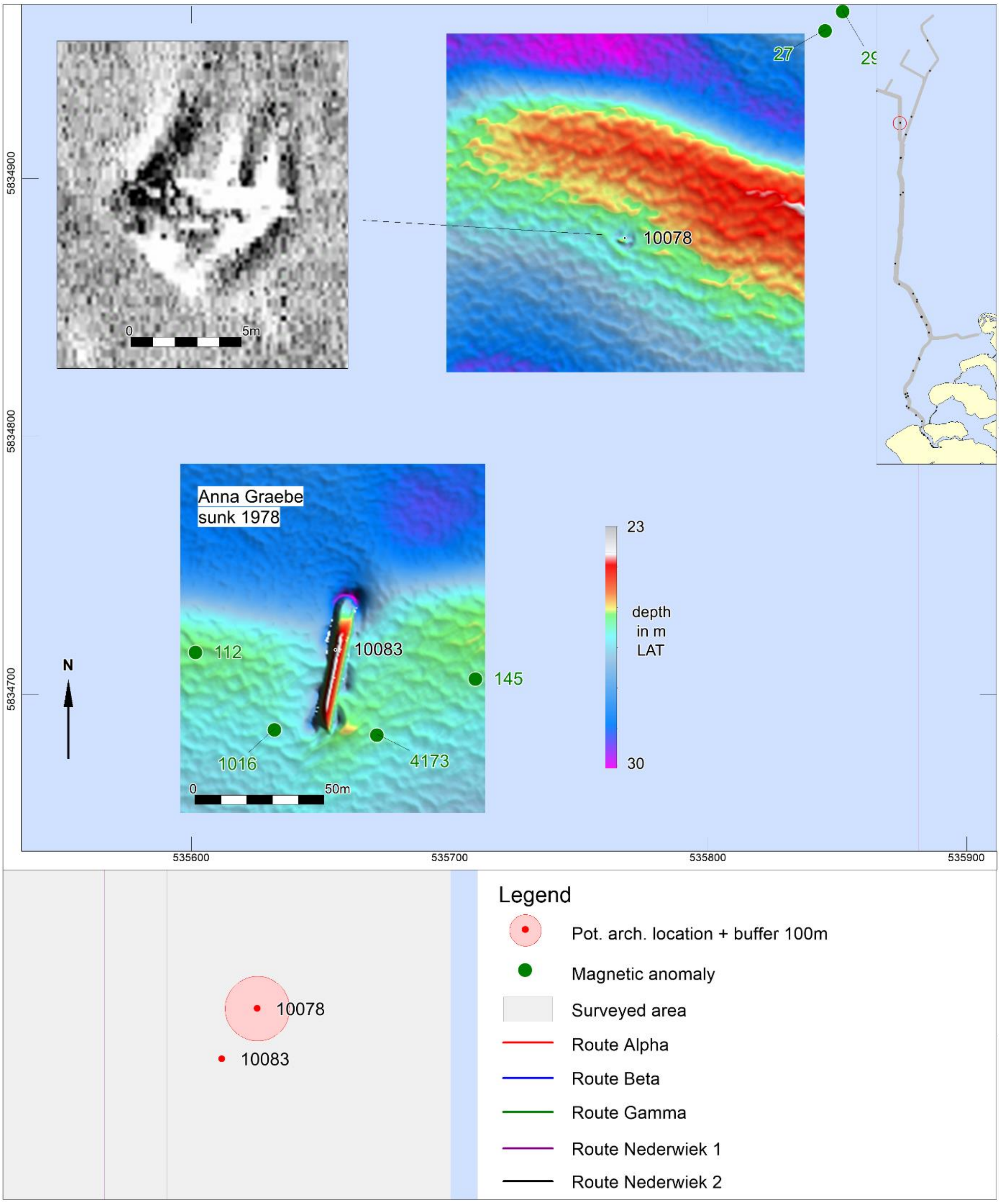
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
3149	Debris linear	11	1	0.2	540080	5837238	-32.0

NCN	Description PPA	Classification PPA	Class
-	Elongated patch of strong reflections, isolated	Possible wreck remains	1



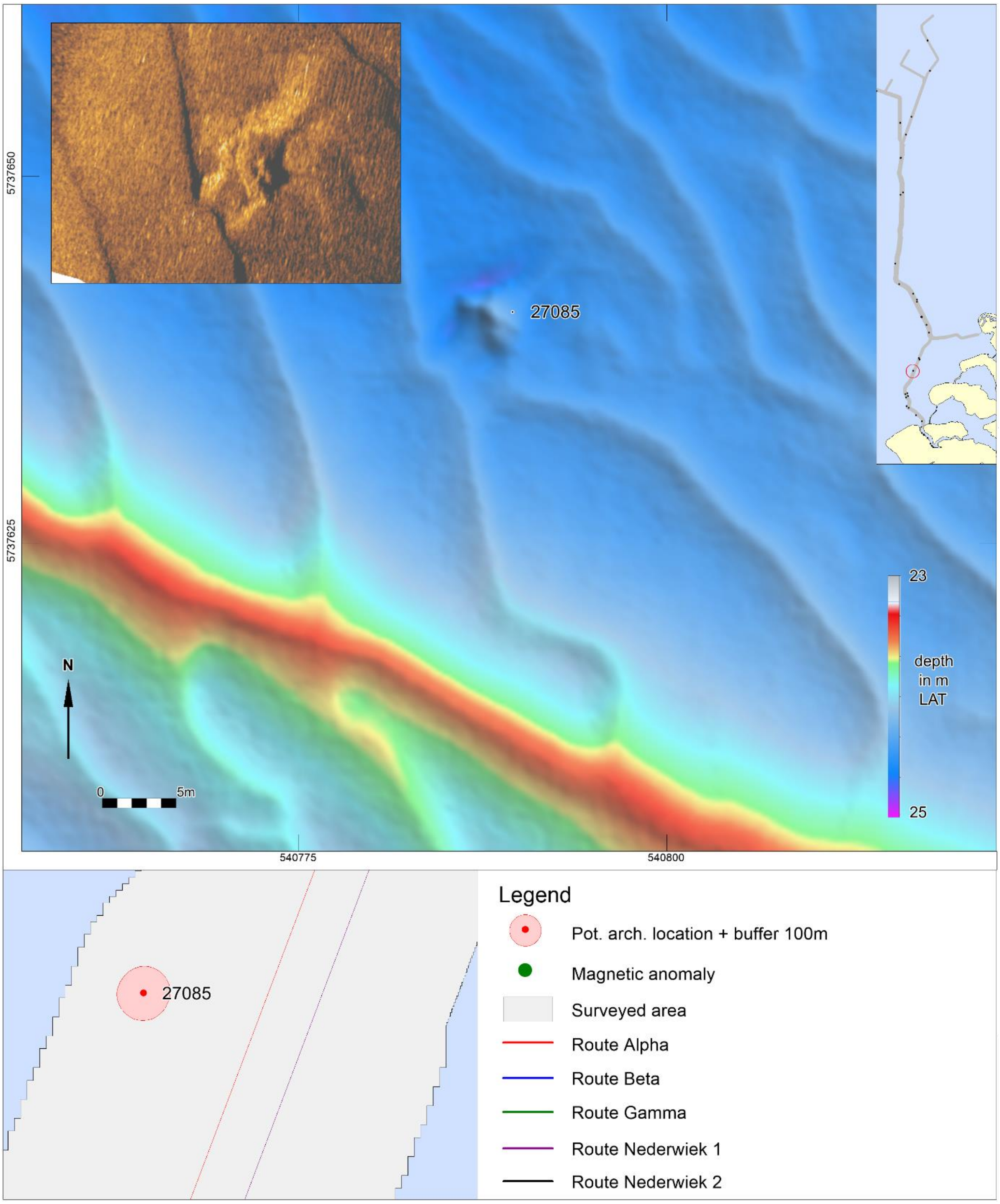
ID	Feature Next	Length	Width	Height	Easting	Northing	KP Alpha
10053	Wreck	29.6	10.6	1.2	535976	5821101	129.037
10059	Wreck	21	8.2	0.2	535882	5821036	128.972

NCN	Description PPA	Classification PPA	Class
2810	Unidentified shipwreck, NCN 2810	Wreck	2
-	Rectangular cluster of small objects, several mag anomalies	Possible wreck remains	1



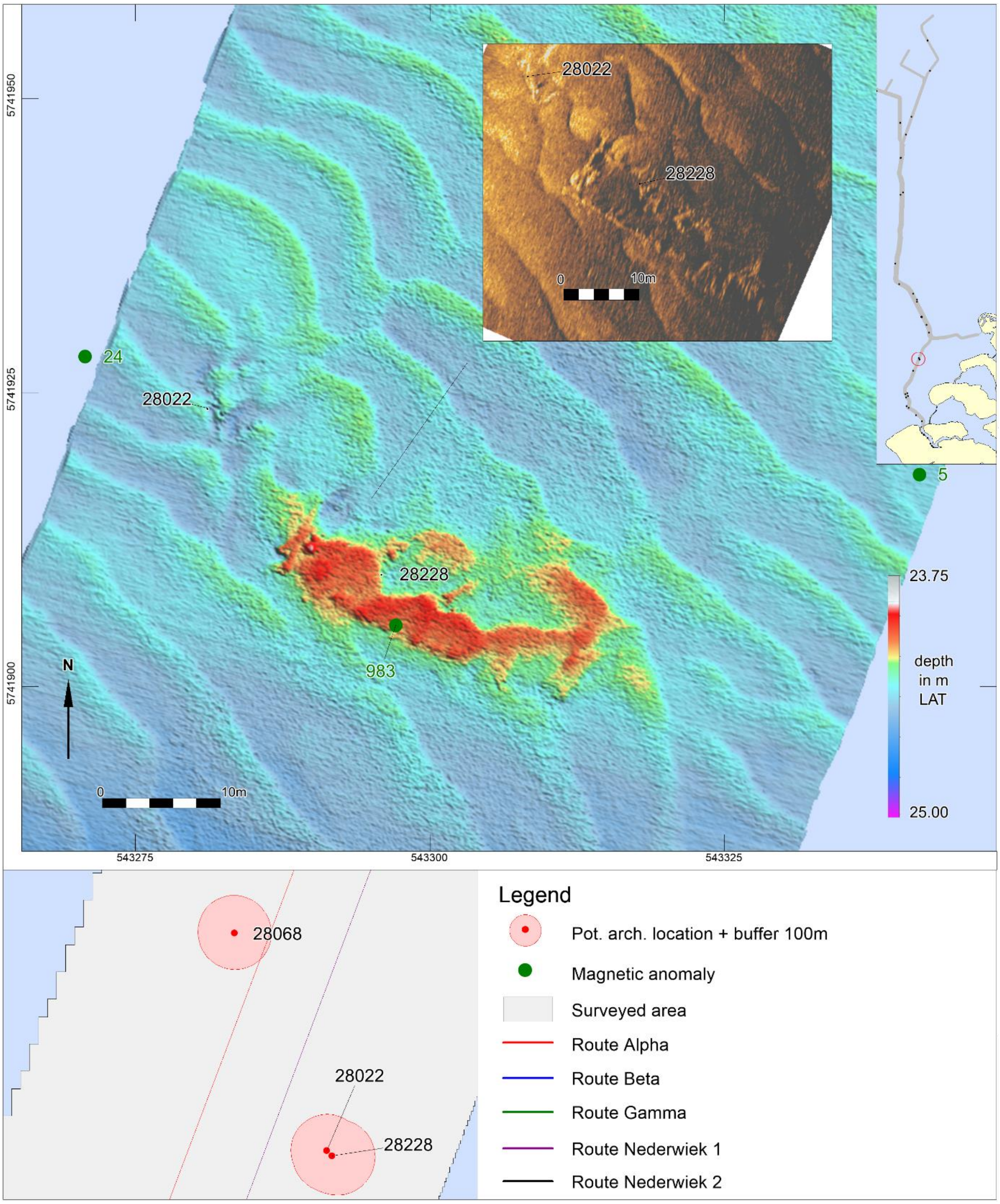
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
10078	Debris other	9.9	6.3	0.8	535768	5834877	-27.9
10083	Wreck	56.3	6.7	2	535656	5834718	-24.8

NCN	Description PPA	Classification PPA	Class
-	Square structure with internal reflectors	Possible wreck remains	1
2081	Wreck *Anna Graebe*, iron freighter sunk 1978 / RCE 4028335100	Wreck	1



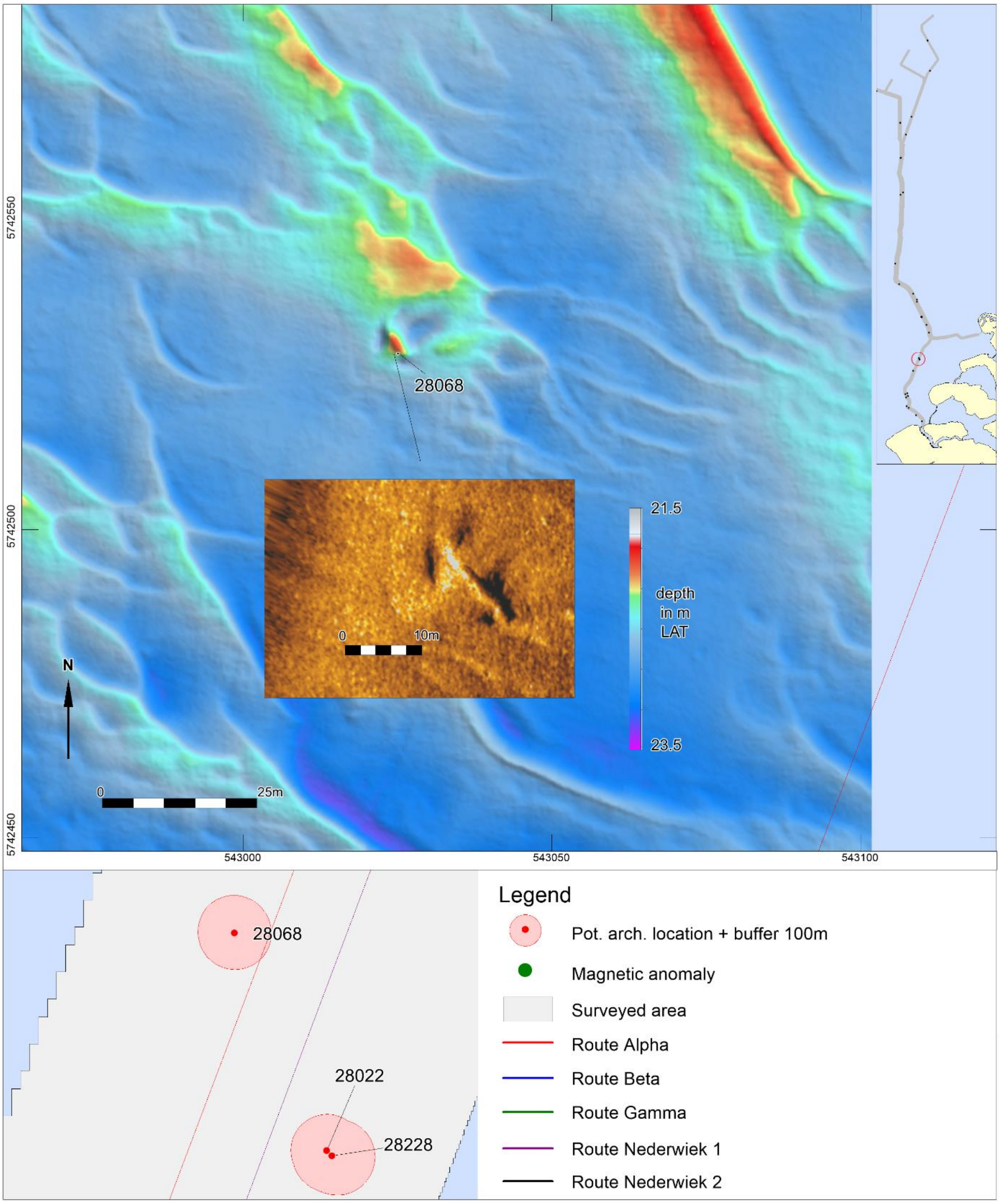
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
27085	Debris linear	15	5	1	540790	5737641	-22.2

NCN	Description PPA	Classification PPA	Class
-	Rectangular structure, relatively high	Possible wreck remains	1



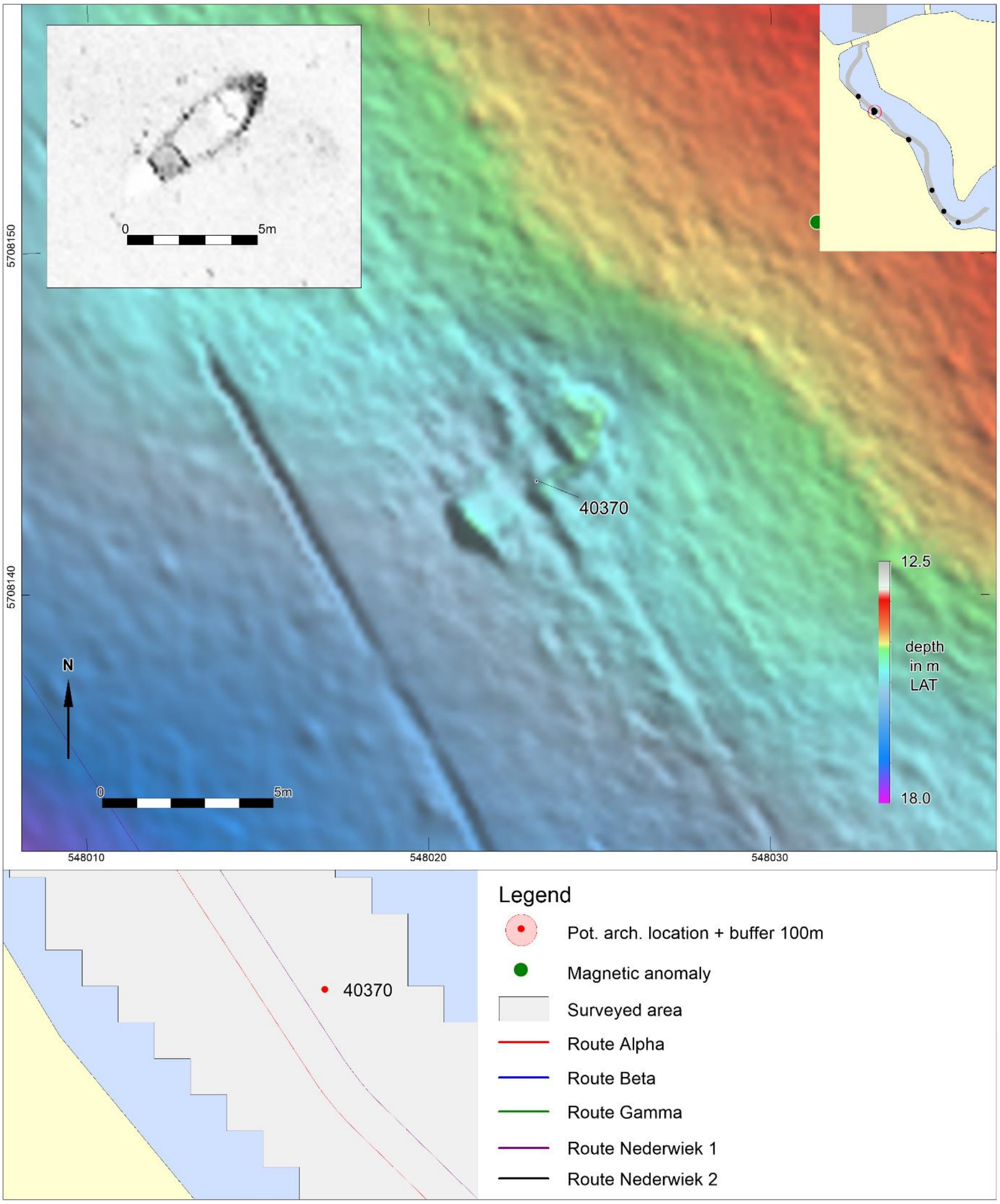
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
28022	Debris linear	4.4	0.5	0.4	543281	5741924	-24.4
28228	Wreck	44.4	9.4	0.3	543296	5741910	-24.3

NCN	Description PPA	Classification PPA	Class
-	Object 2 x 2 m 10m NW of wreck	Wreck remains	1
-	Large structure 28 x 10m, probably wreck. Mag anomaly 983 nT	Wreck	2



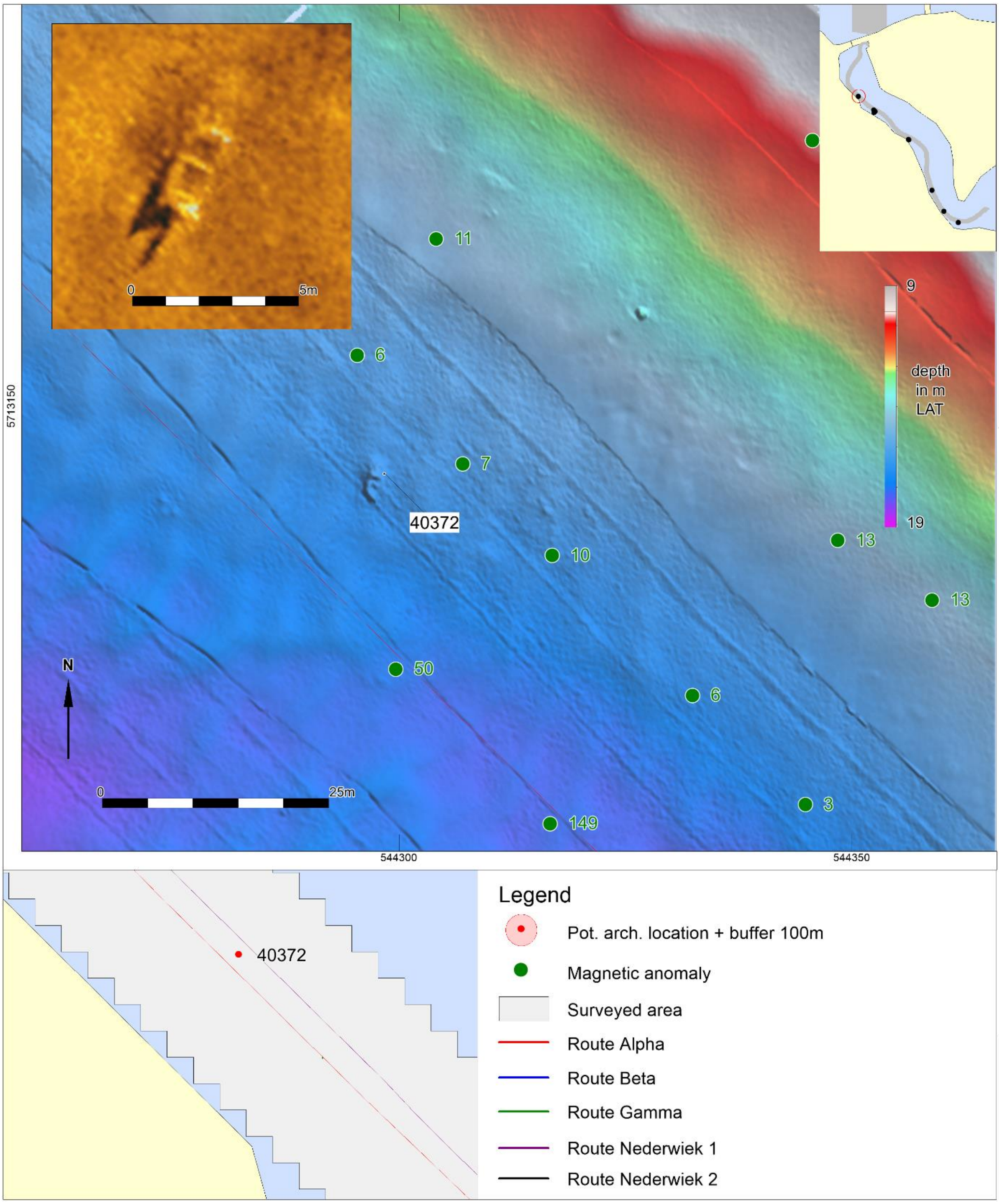
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
28068	Debris linear	13.4	1.6	0.9	543025	5742529	-22.1	43.811

NCN	Description PPA	Classification PPA	Class
-	Elongated structure with scouring	Possible wreck remains	1



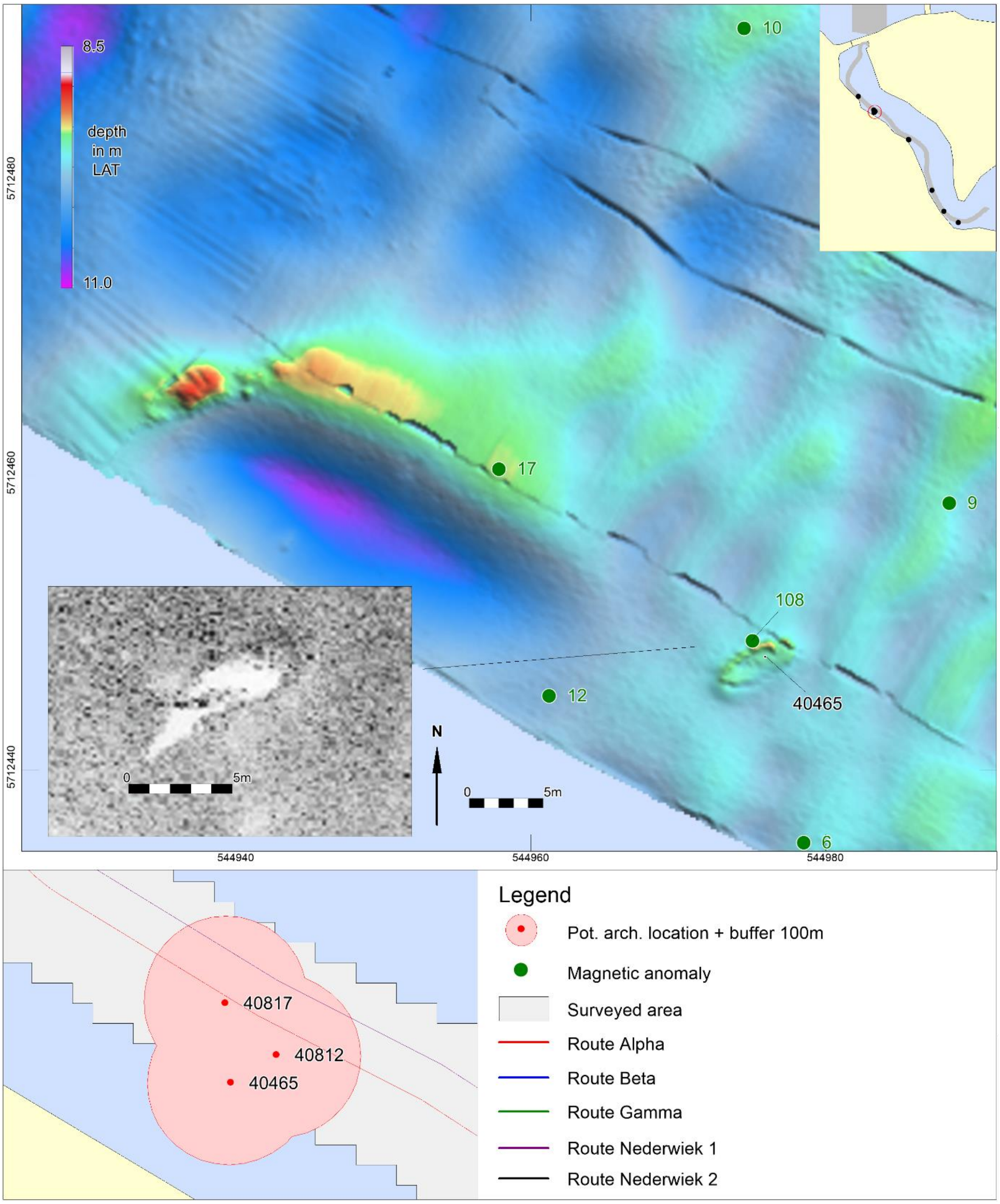
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
40370	Wreck	5.5	2.1	0.5	548023	5708143	-15.1

NCN	Description PPA	Classification PPA	Class
-	Small wreck, probably recent sloop	Wreck, recent	1



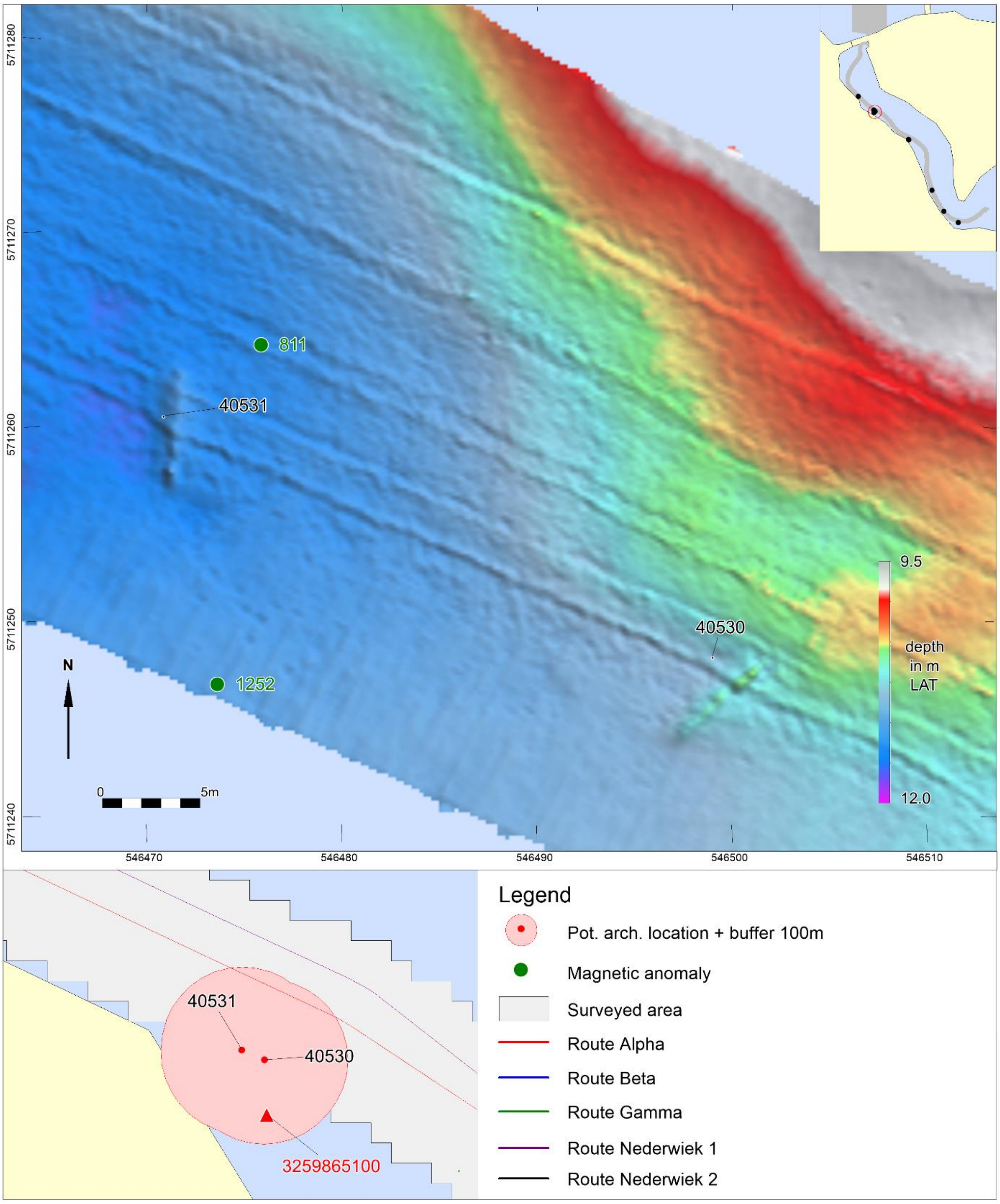
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
40372	Wreck	4	1.9	0.4	544298	5713143	-16.3	8.925

NCN	Description PPA	Classification PPA	Class
-	Small wreck, probably recent sloop	Wreck, recent	1



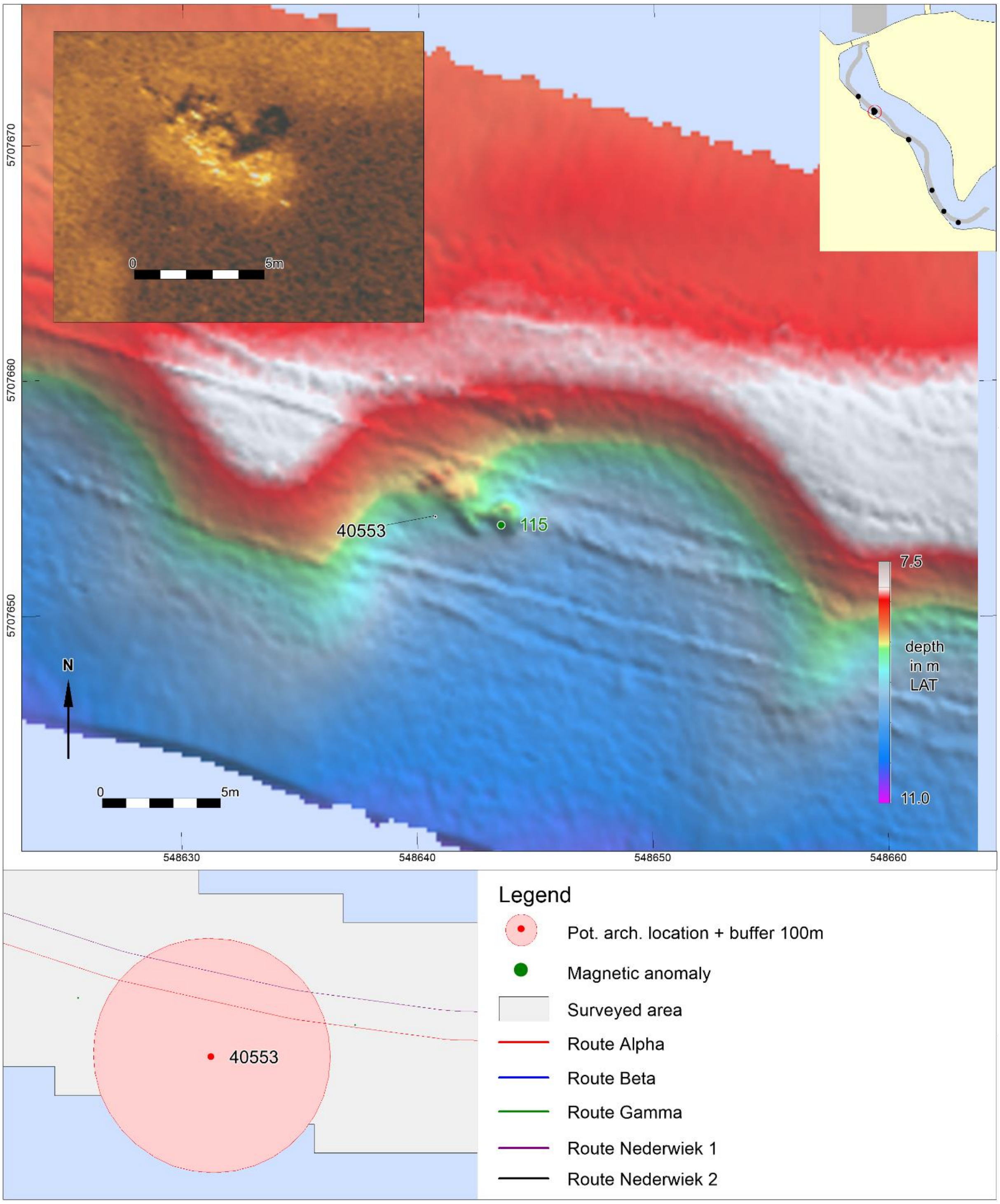
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
40465	Wreck	5.5	3.1	0.9	544976	5712448	-9.5	7.972

NCN	Description PPA	Classification PPA	Class
-	Small wreck, probably recent sloop	Wreck, recent	1



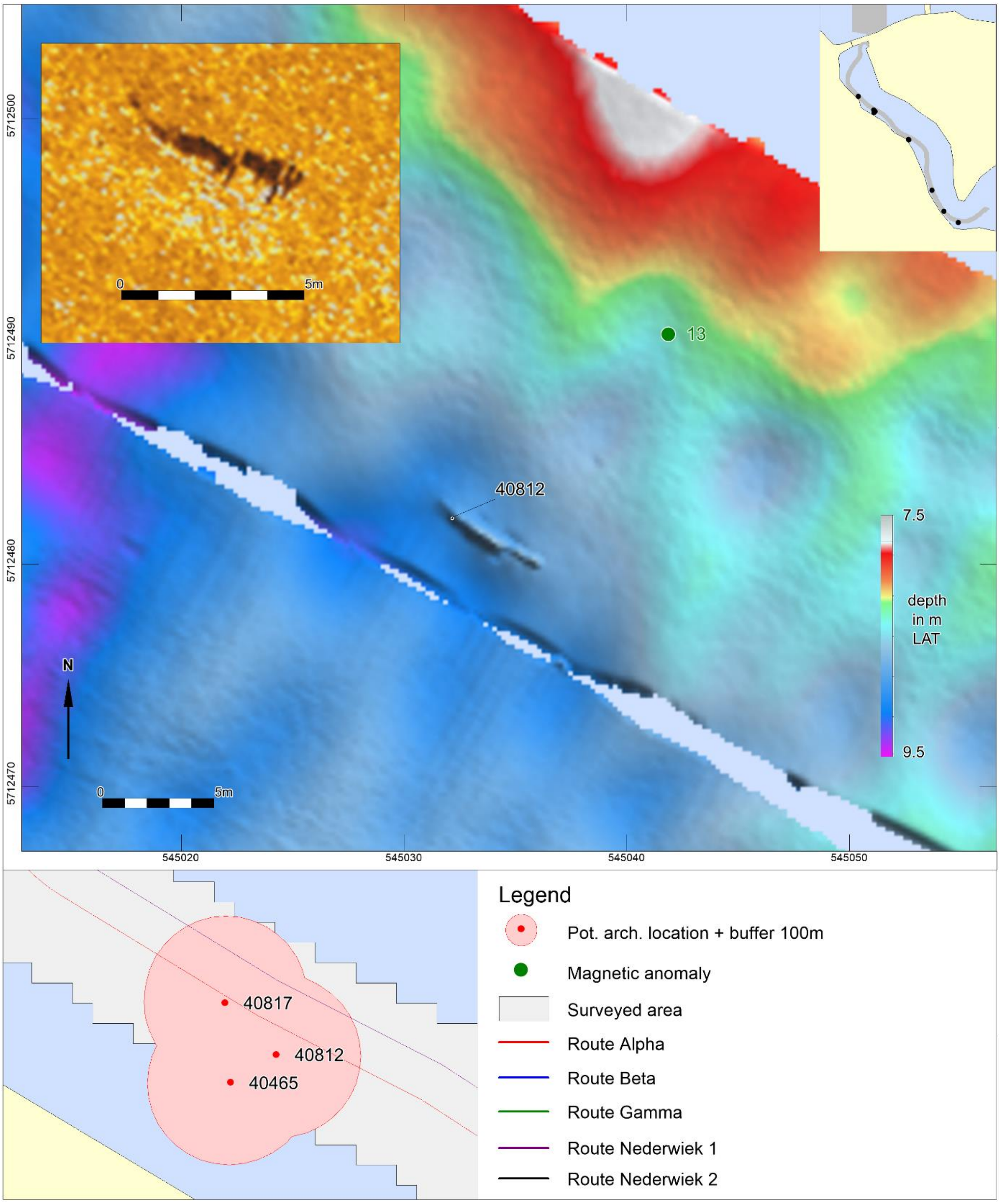
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
40530	Debris linear	5	0.8	0.3	546499	5711248	-10.6	6.001
40531	Debris linear	8.5	0.7	0.2	546471	5711261	-11.4	6.031

NCN	Description PPA	Classification PPA	Class
-	Elongated structure, irregular - possibly related to RCE 3259865100	Wreck remains	2
-	Elongate structure or lineation of objects, l 5.5 m, mag anomalies, possibly related to RCE 3259865100	Wreck remains	2



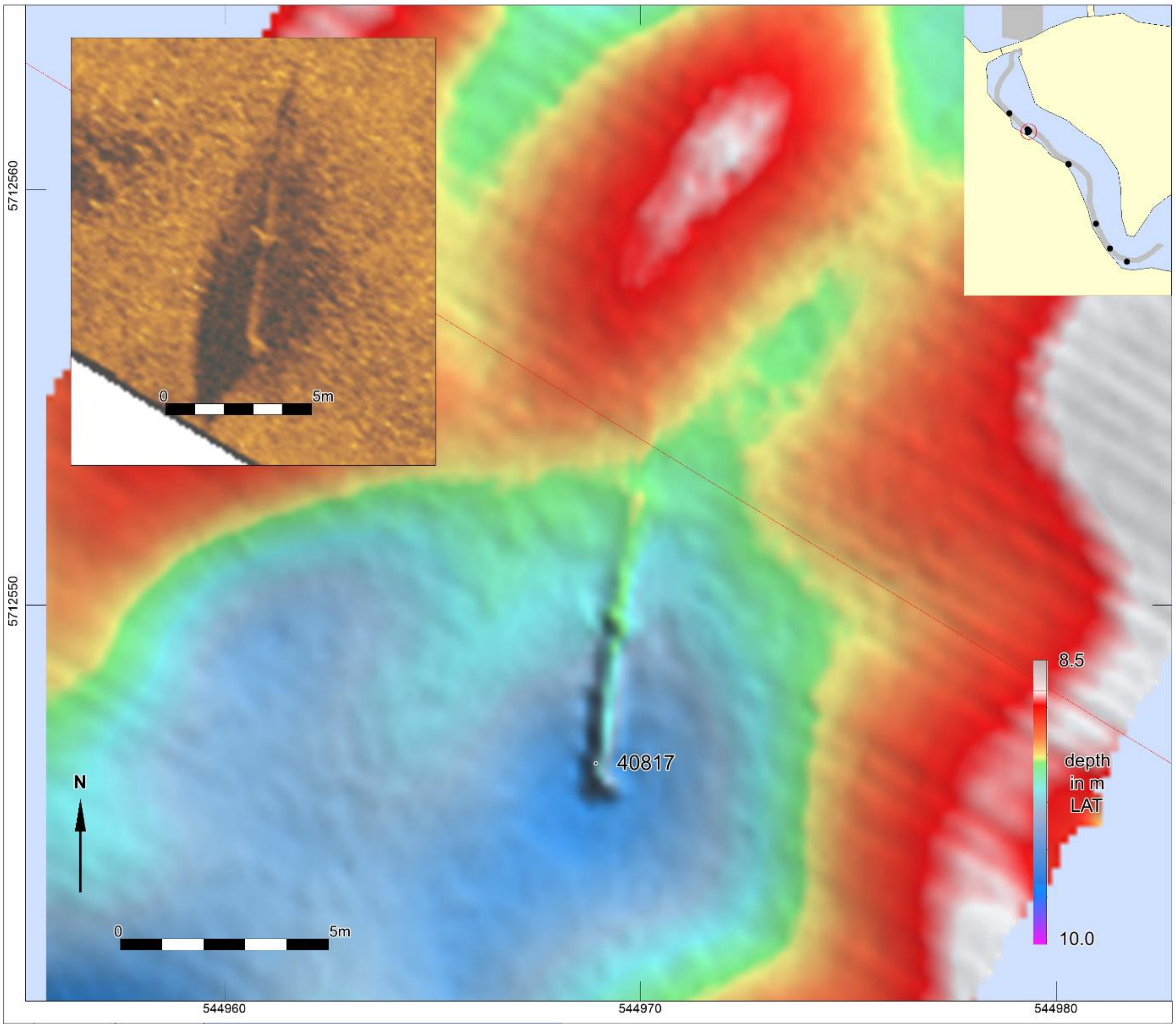
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP 1.493
40553	Debris other	6.3	3.5	0.7	548641	5707654	-8.7	

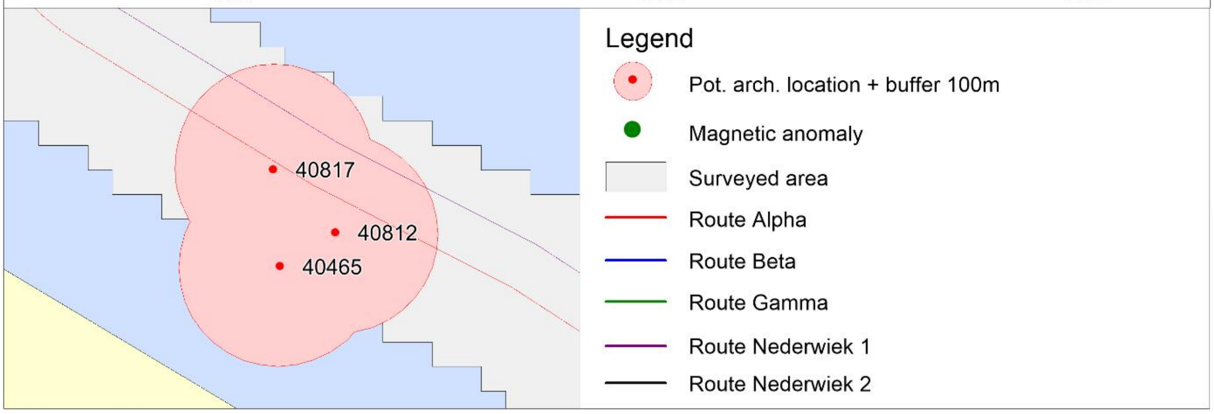
NCN	Description PPA	Classification PPA	Class	Buffer
-	Irregular object 7 x 2.5, possible wreck remains	Wreck remains	1	Yes



ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
40812	Debris linear	5.2	0.2	0.7	545032	5712482	-8.8	7.938

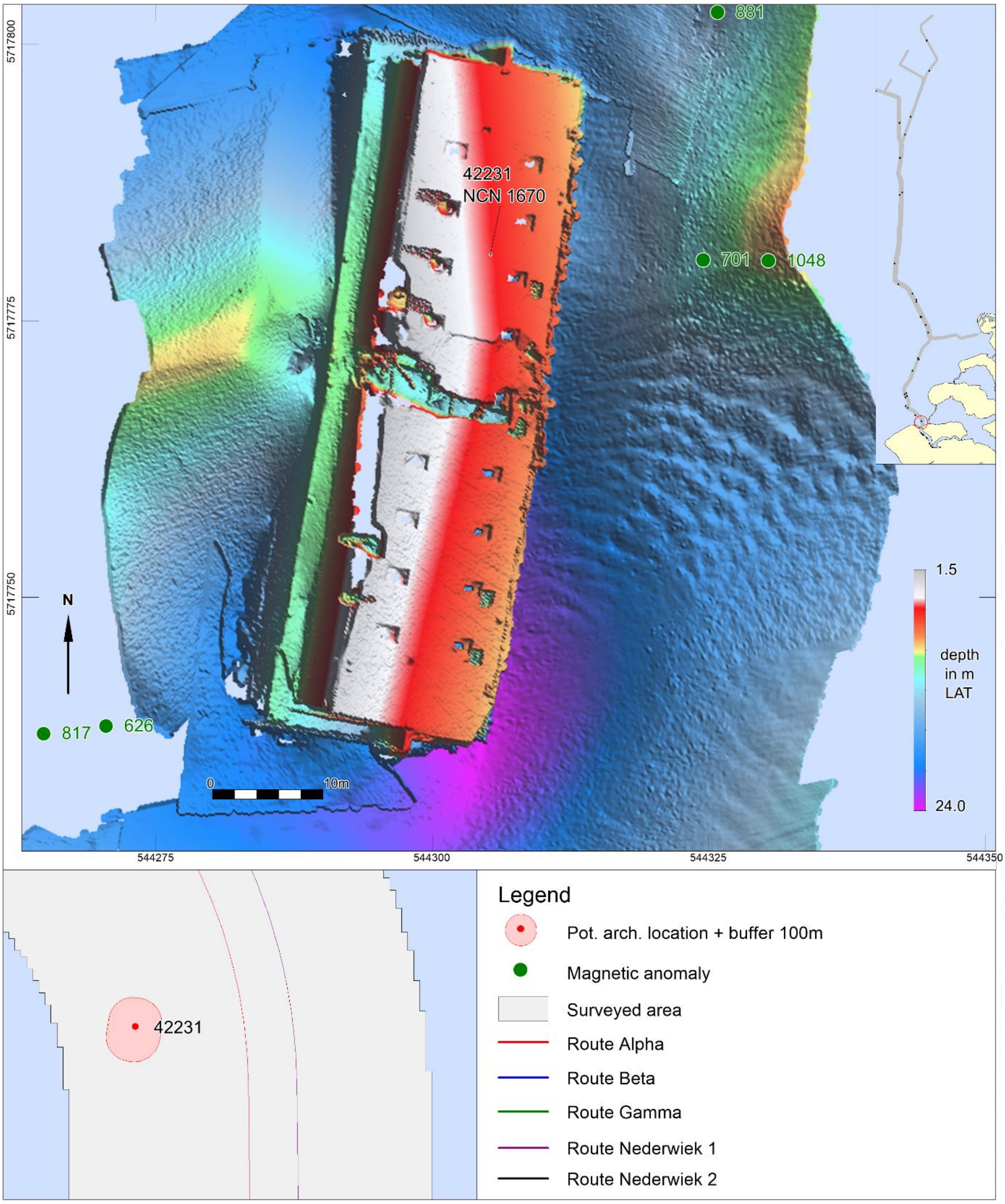
NCN	Description PPA	Classification PPA	Class
-	Irregular elongated object, slightly bended	Wreck remains	1





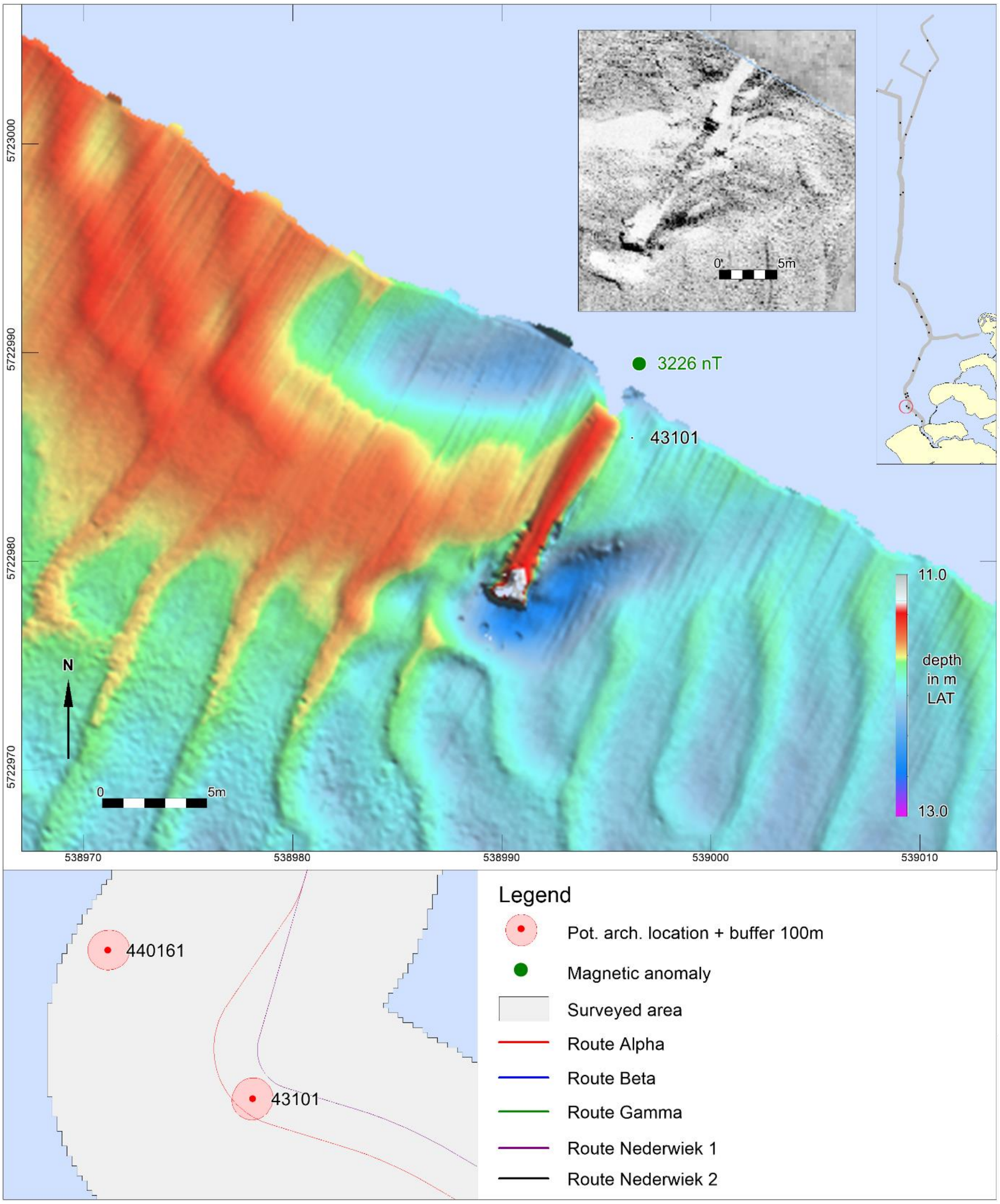
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
40817	-	1.2	1.7	0.9	544969	5712546	-9.4	8.023

NCN	Description PPA	Classification PPA	Class
-	Elongated object 9.8 x 1.4 m, bended at southern end, no mag., possible part of wreck	Wreck remains	1



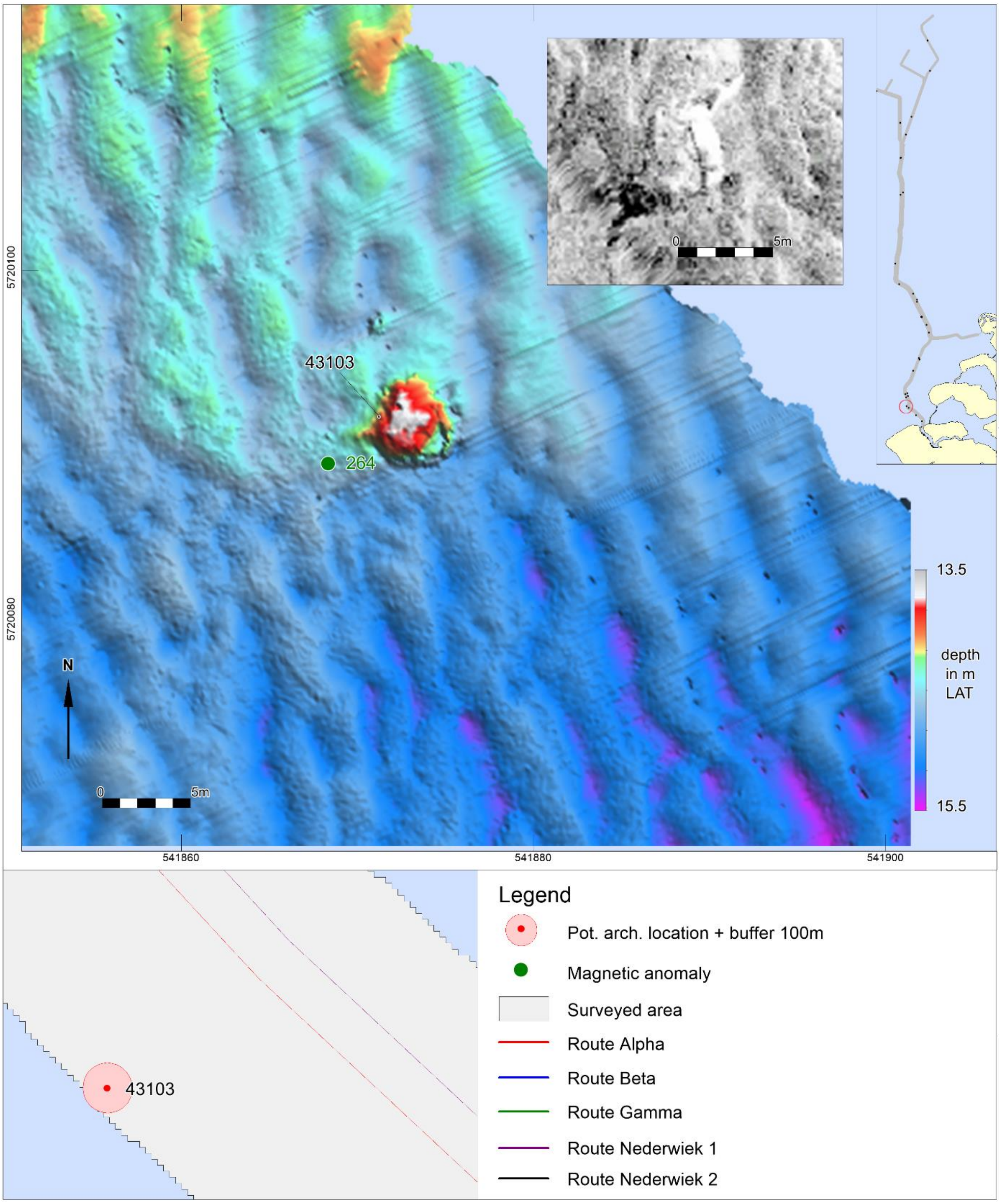
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
42231	Wreck	63.9	23.5	1.8	544305	5717781	-4.9

NCN	Description PPA	Classification PPA	Class
1670	Caisson, concrete, sunk 15-09-1953. wreck NCN 1670	Wreck	2



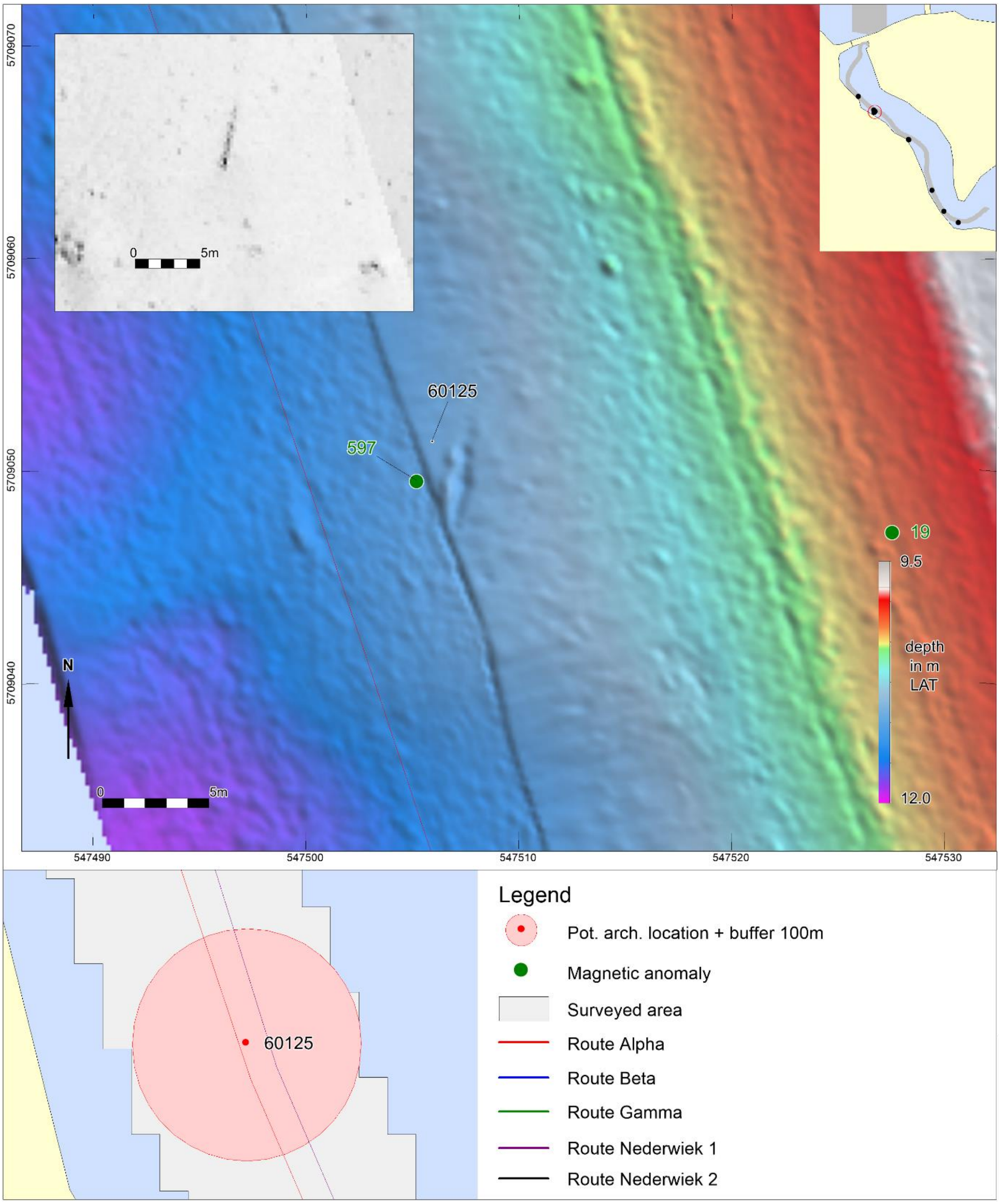
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
43101	Wreck	19.4	2.5	0	538996	5722986	-11.9	22.311

NCN	Description PPA	Classification PPA	Class
-	Large object 15 x 2.5 m, probably wreck, large anomaly 3225 nT	Wreck	2



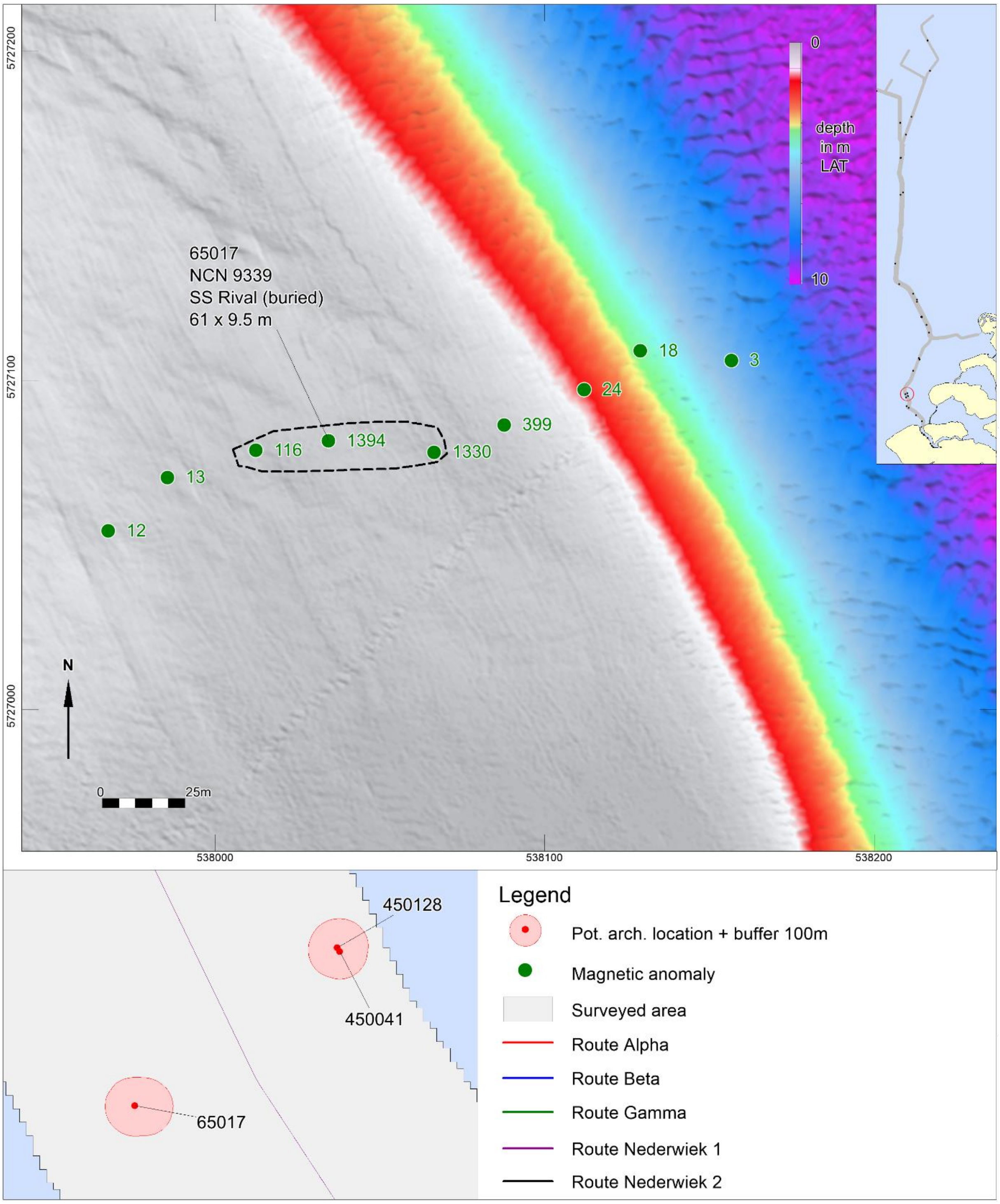
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
43103	Wreck	5.1	3.1	2.4	541871	5720092	-13.9

NCN	Description PPA	Classification PPA	Class
-	Partly buried structure 9 x 5 m, probably wreck	Wreck	2



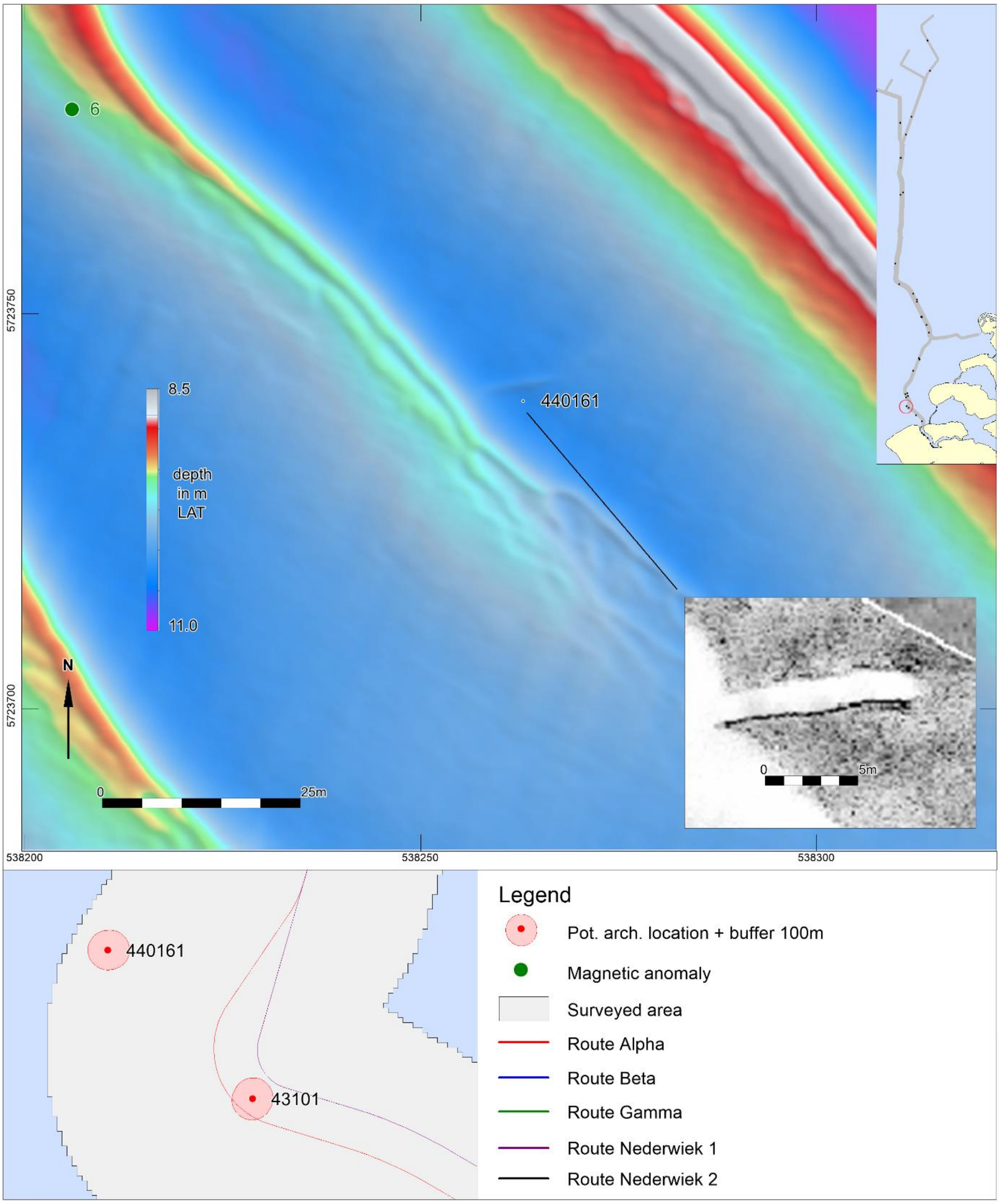
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Alpha
60125	Debris linear	6.7	0.4	0	547506	5709051	-13.8	3.353

NCN	Description PPA	Classification PPA	Class
-	Elongate object, large MAG 597 nT	Possible wreck remains	1



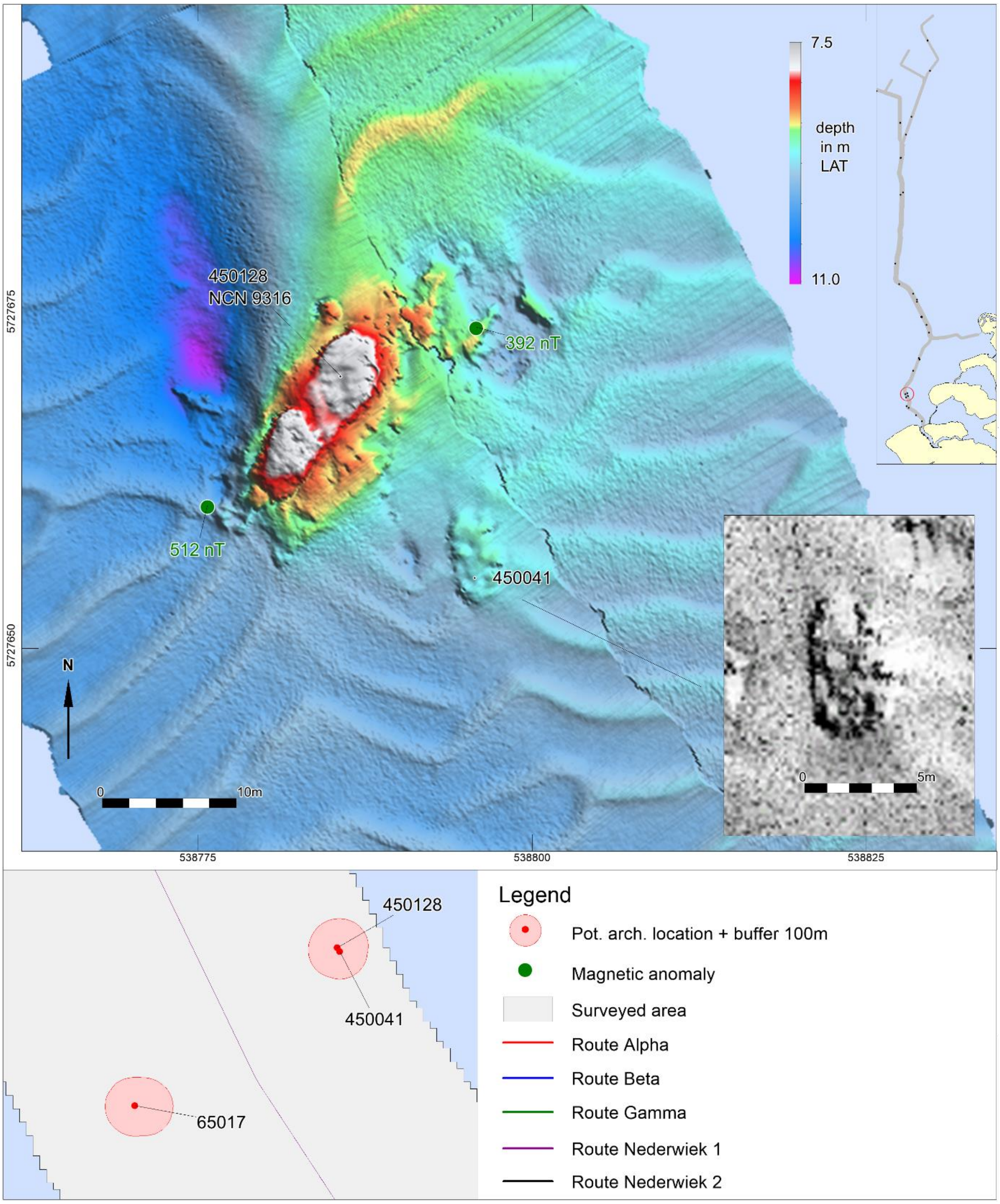
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
65017	Wreck				538034	5727082	-0.4

NCN	Description PPA	Classification PPA	Class
9339	Location NCN 9339, buried remains SS Rival, sunk 31-12-1944, covered with >2m sediment. RCE 3175138100	Wreck	2



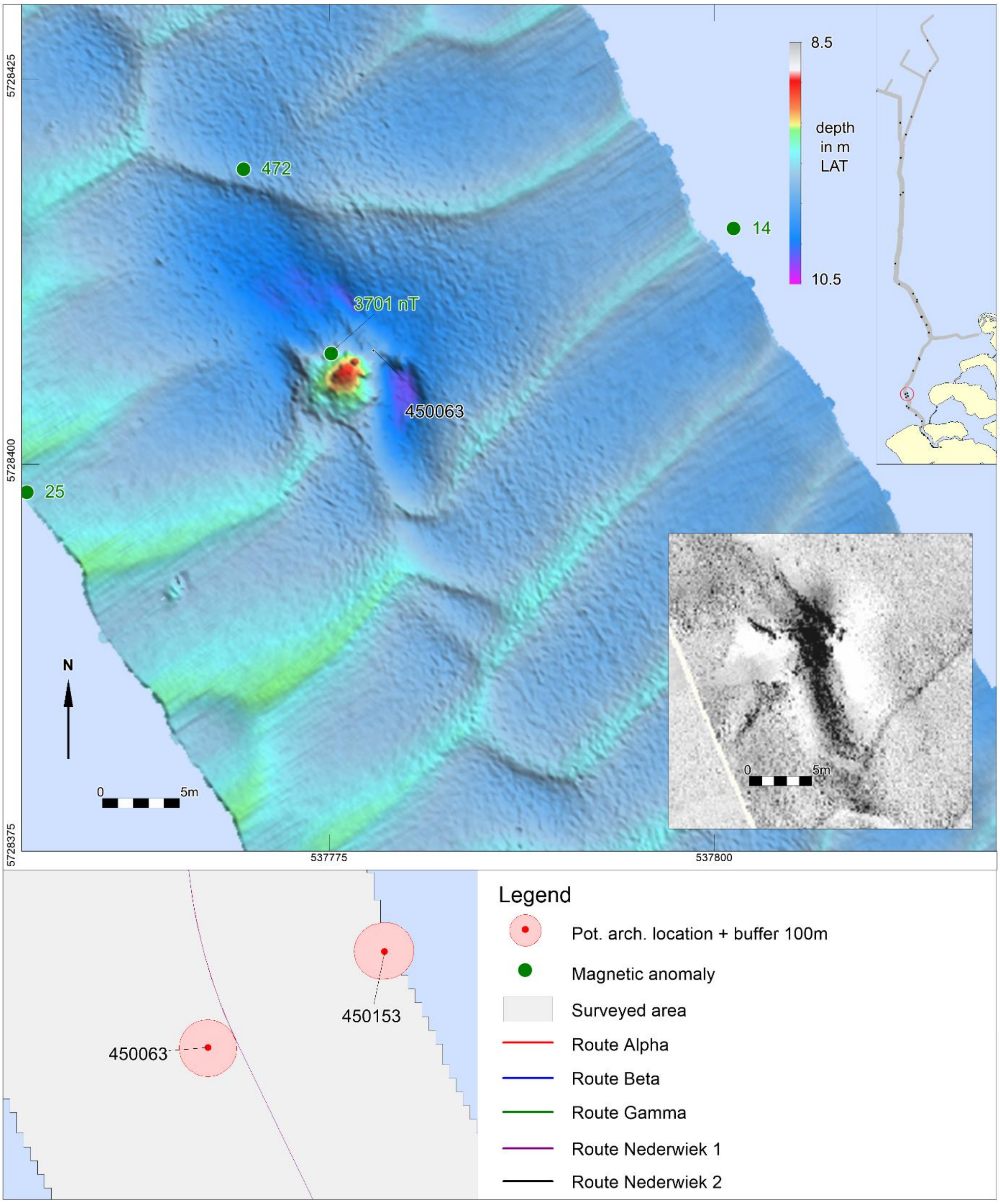
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
440161	Debris linear	10.4	0.2	0.3	538263	5723739	-10.4

NCN	Description PPA	Classification PPA	Class
-	Elongated structure perpendicular to sand ripples	Possible wreck remains	1



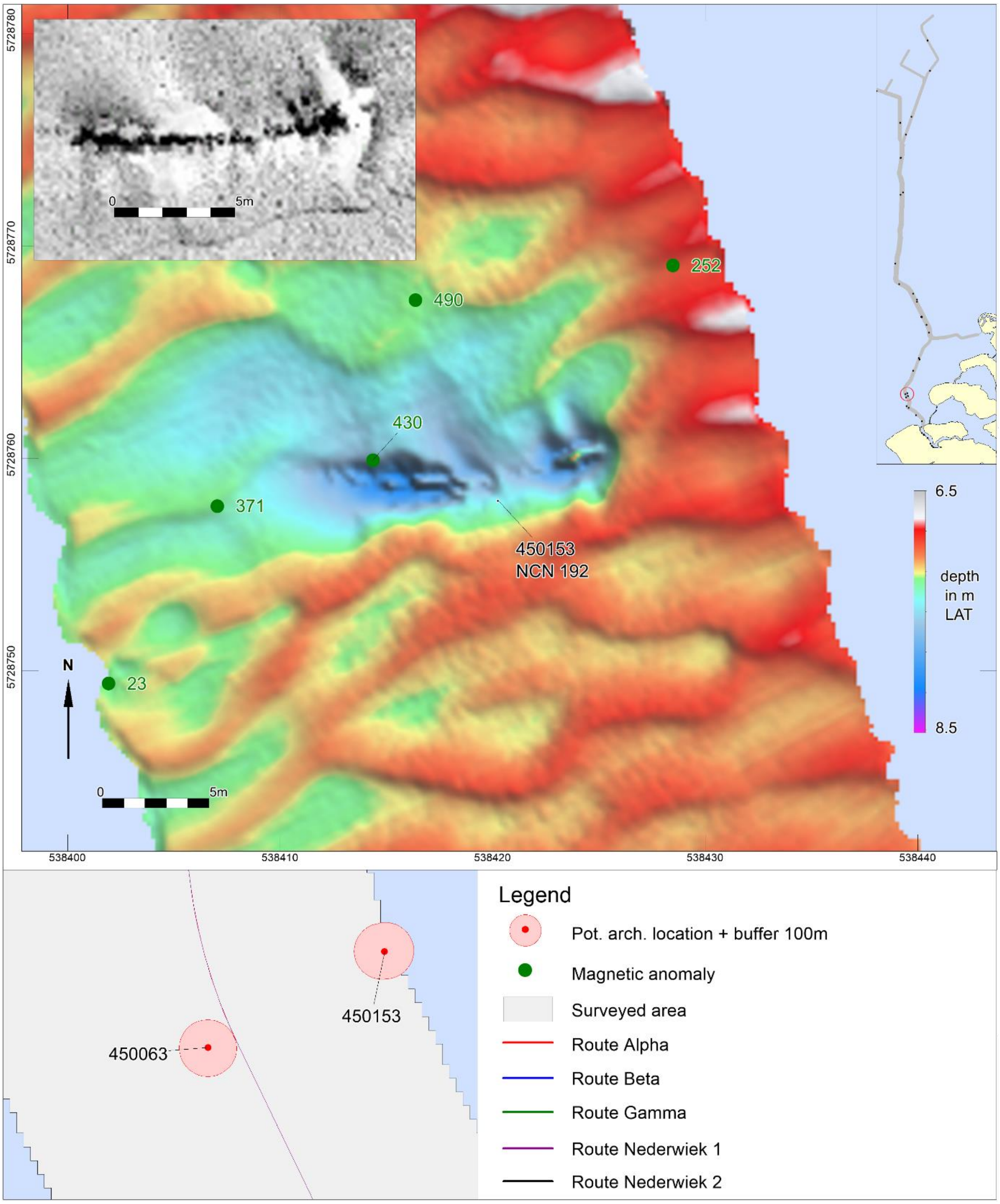
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
450041	Wreck	6.9	3.7	0.8	538796	5727655	-9.1
450128	Wreck	13.5	12.5	2.3	538786	5727670	-7.7

NCN	Description PPA	Classification PPA	Class
-	Structure 7 x 3 30m SE of NCN 9316, small wreck? Or remains of NCN 9316	Wreck	2
9316	Unidentified wreck, NCN 9316 / RCE 2910065100, cargo iron ingots	Wreck	2



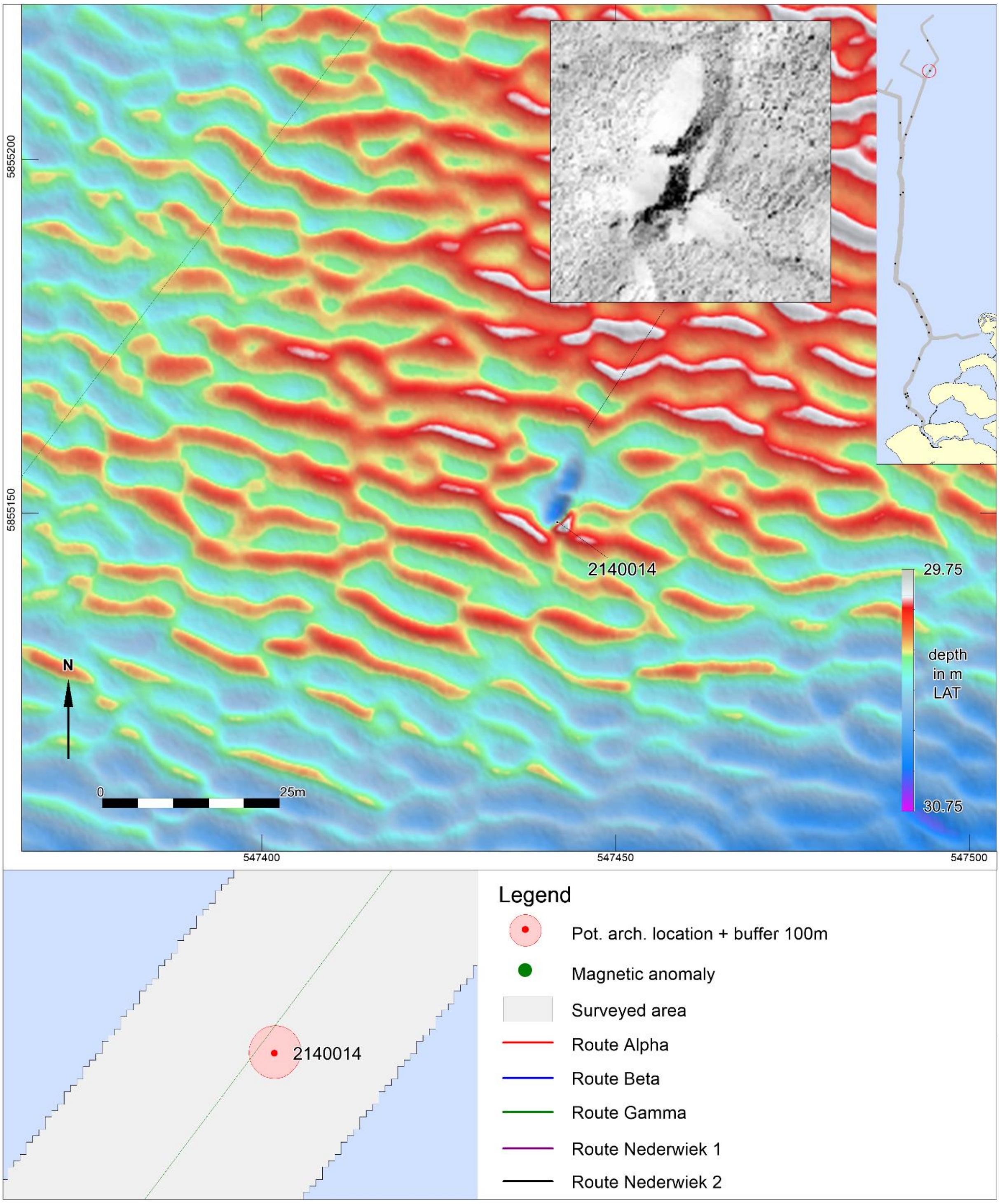
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
450063	Wreck	5.5	4.9	1.1	537778	5728407	-9.0

NCN	Description PPA	Classification PPA	Class
-	Partly buried structure 9 x 5 m, probably wreck, large MAG anomaly 3702 nT	Wreck	2



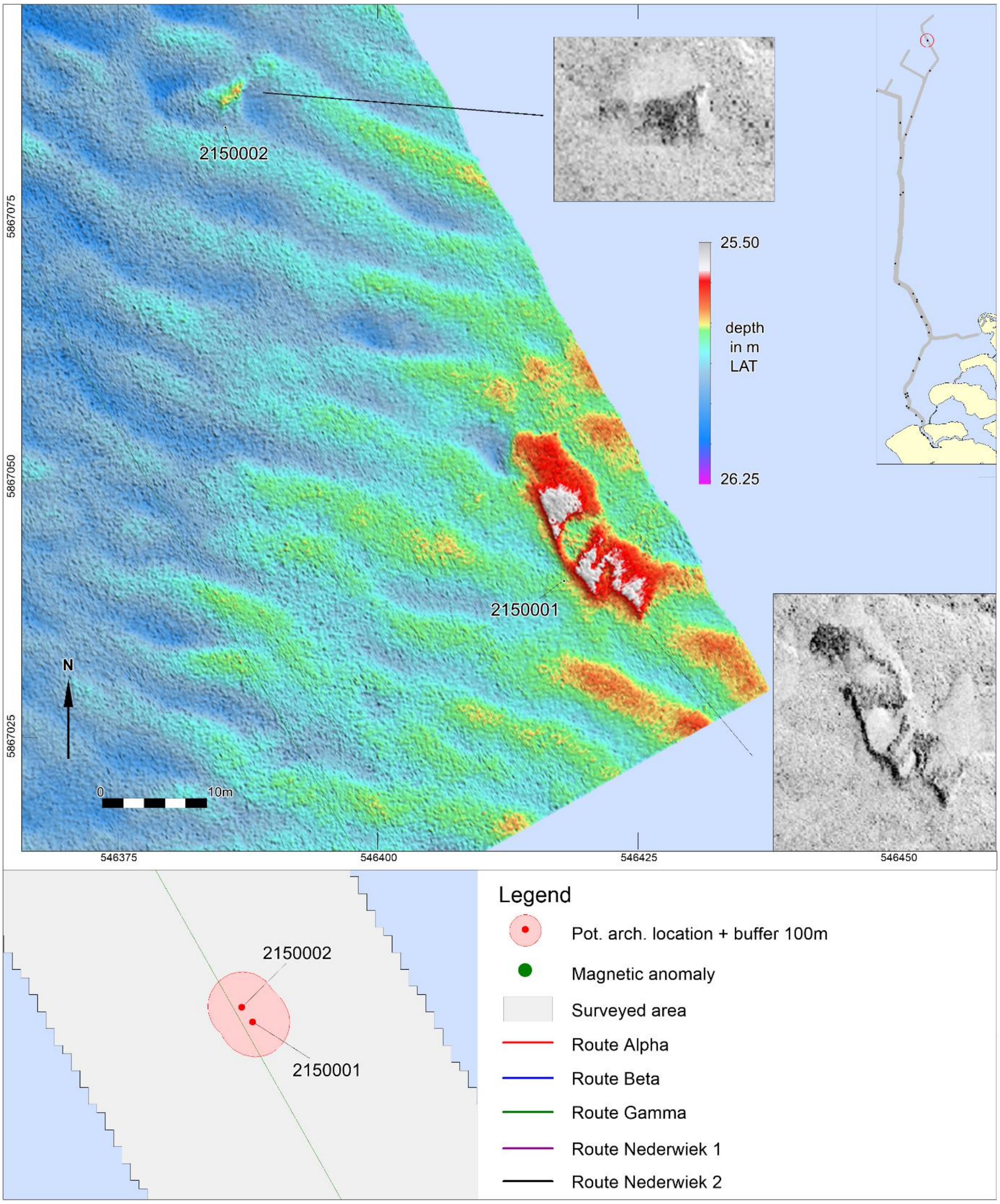
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth
450153	Wreck	12.1	0.8	0.5	538420	5728758	-7.4

NCN	Description PPA	Classification PPA	Class
192	Unidentified wreck remains, NCN 192 / RCE 3045019100	Wreck	2



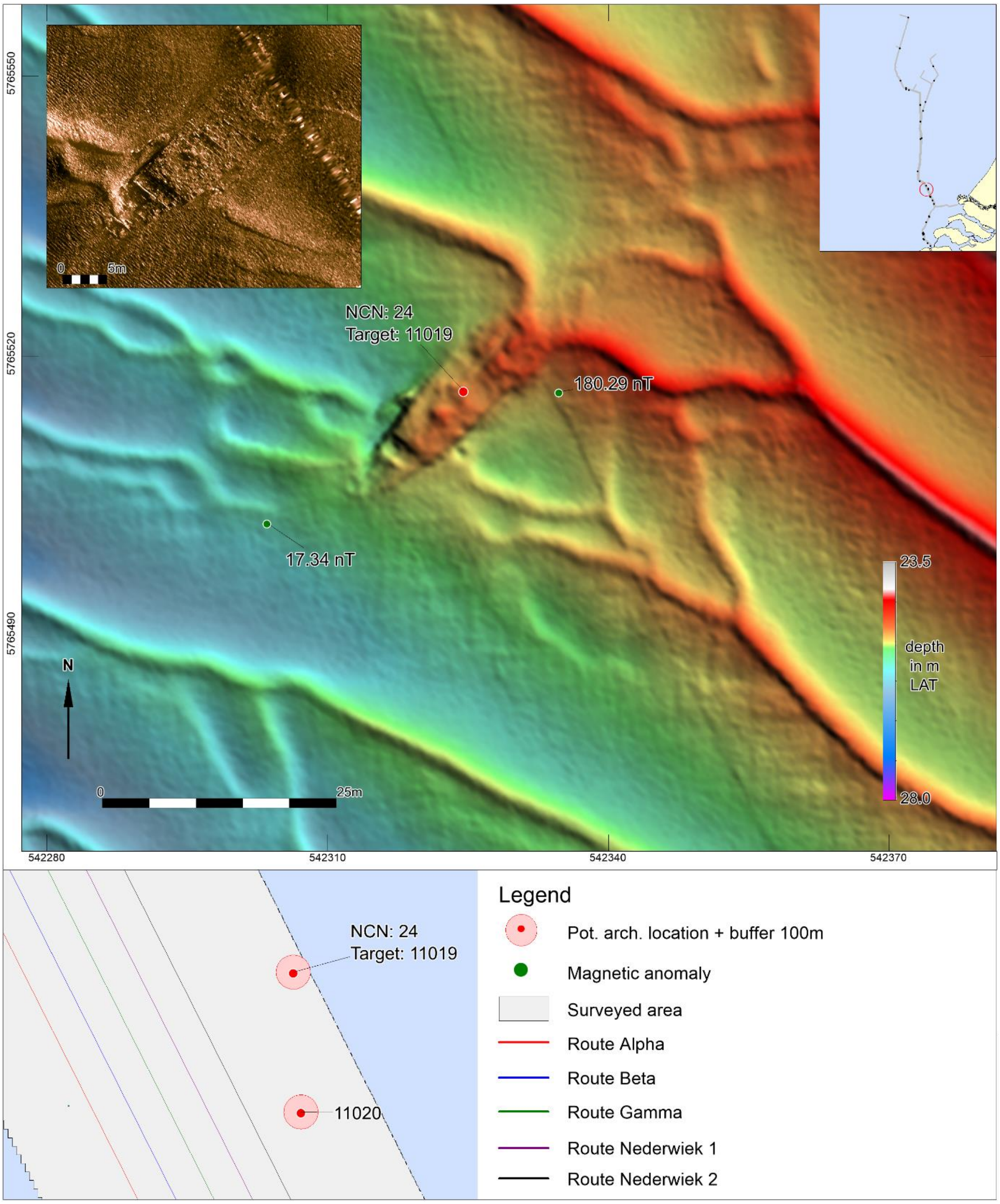
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Gamma
2140014	Debris other	7.5	1.3	0.7	547442	5855149	-30.5	132.850

NCN	Description PPA	Classification PPA	Class
-	Cluster of irregular objects, relative high	Possible wreck remains	1



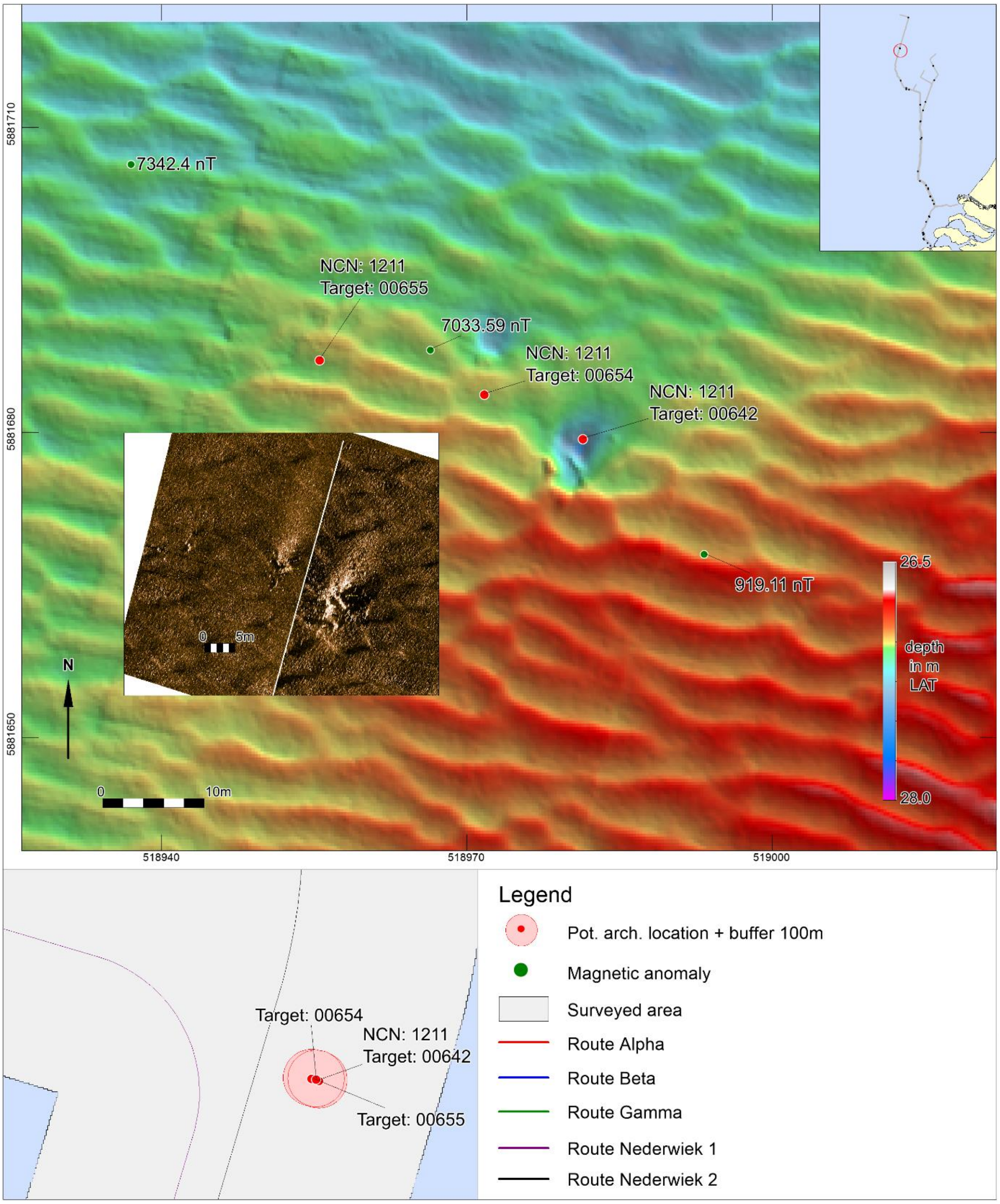
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Gamma
2150001	Wreck	20.9	1.1	0.7	546418	5867040	-25.8	146.801
2150002	Wreck	4.9	4.2	0.3	546385	5867084	-25.9	146.855

NCN	Description PPA	Classification PPA	Class
-	Large structure 20 x 6m, possible wreck, may be geology	Possible wreck remains	1
-	Elongated object 3.2 x 2m 40m N of possible wreck remains	Possible wreck remains	1



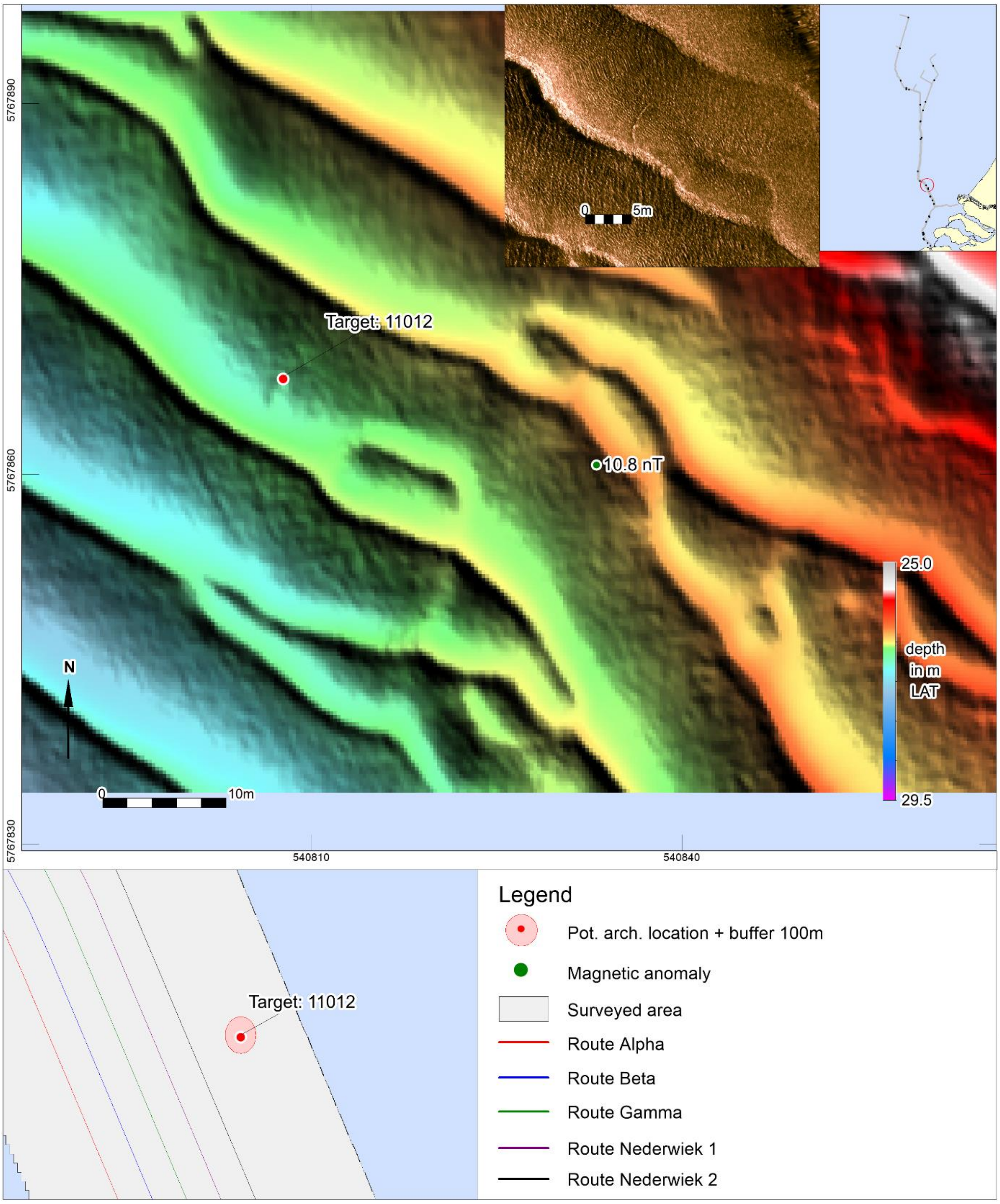
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP Gamma
11019	Wreck	27.1	7.5	0.7	542324	5765516	-25.1	37.179

NCN	Description PPA	Classification PPA	Class
24	Unidentified wreck, wood. NCN 24	Wreck	2



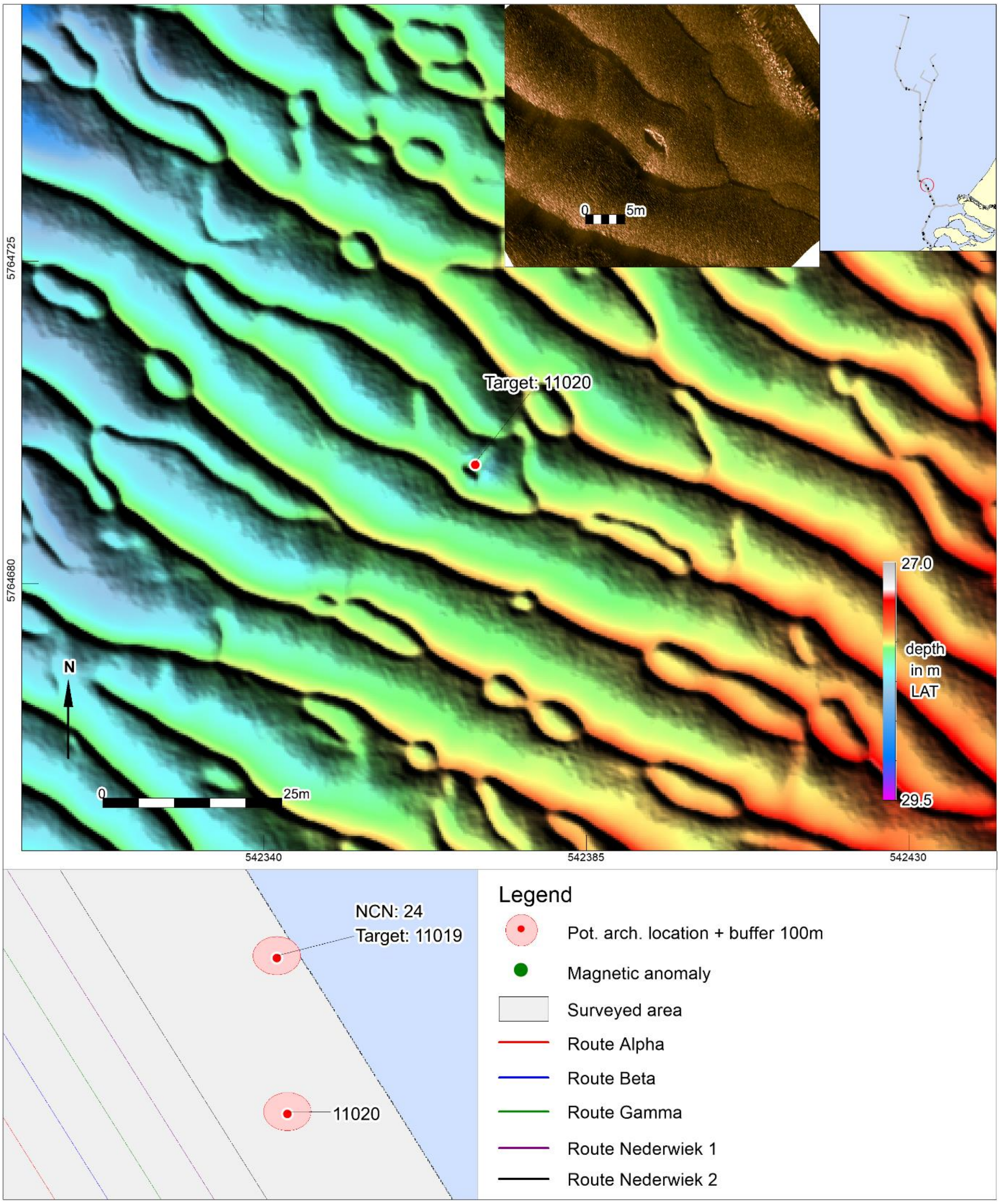
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
00642 00655	Wreck Wreck	10.7 2.9	4.5 0.8	0.4 0.1	518981 518956	5881679 5881687	-27.7 -27.2	170.013 170.013
00654	Wreck	4.7	2.0	0.3	518972	5881684	-27.2	170.014

NCN	Description PPA	Classification PPA	Class
1211	Unidentified wreck, NCN 1211; partially buried by a sand wave	Wreck	2



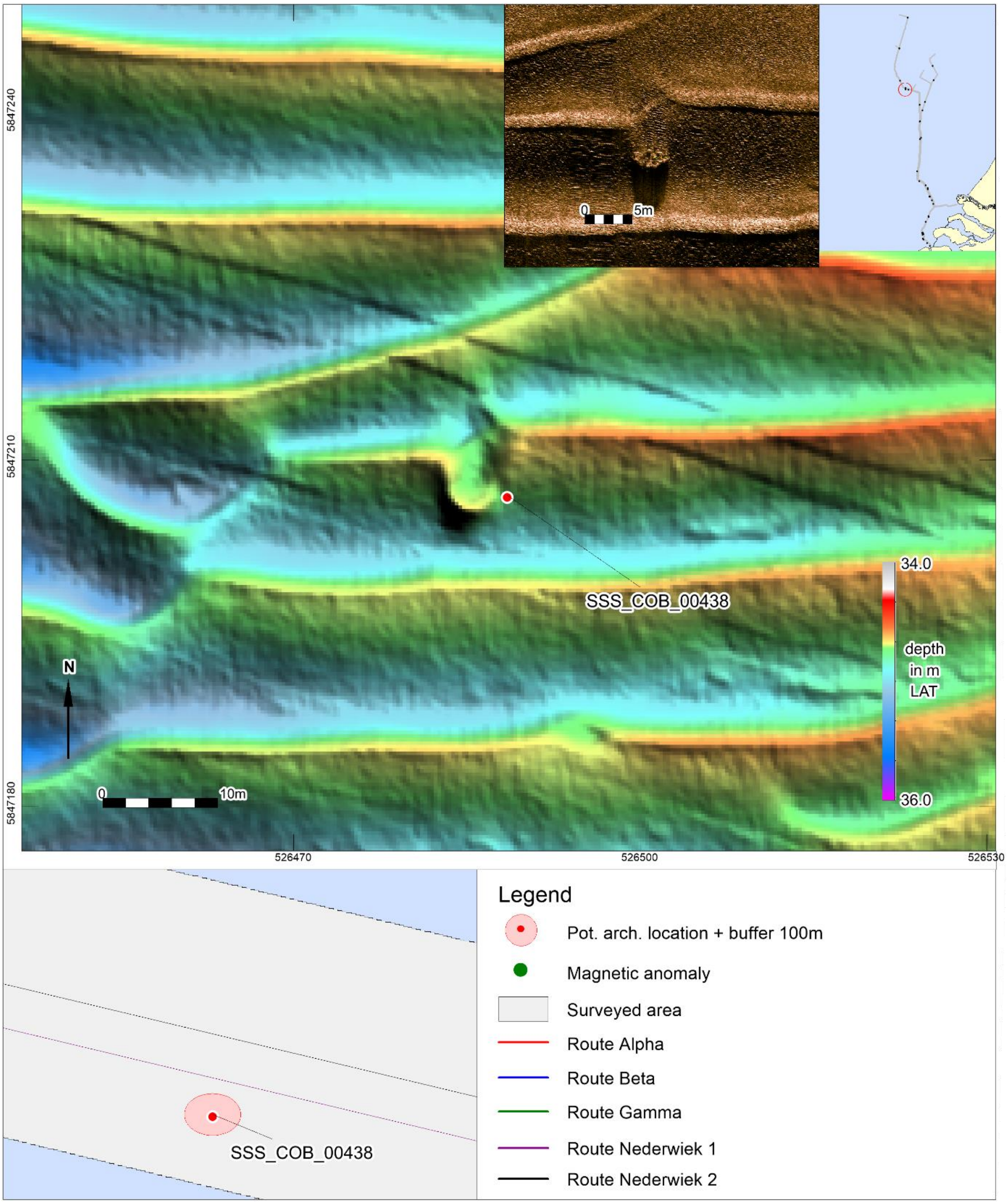
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
11012	Debris Linear	5.0	0.2	0.0	540808	5767868	-27.7	39.962

NCN	Description PPA	Classification PPA	Class
-	Partially buried structure, 17.3 x 5.4 m, possible wreck	Possible wreck remains	1



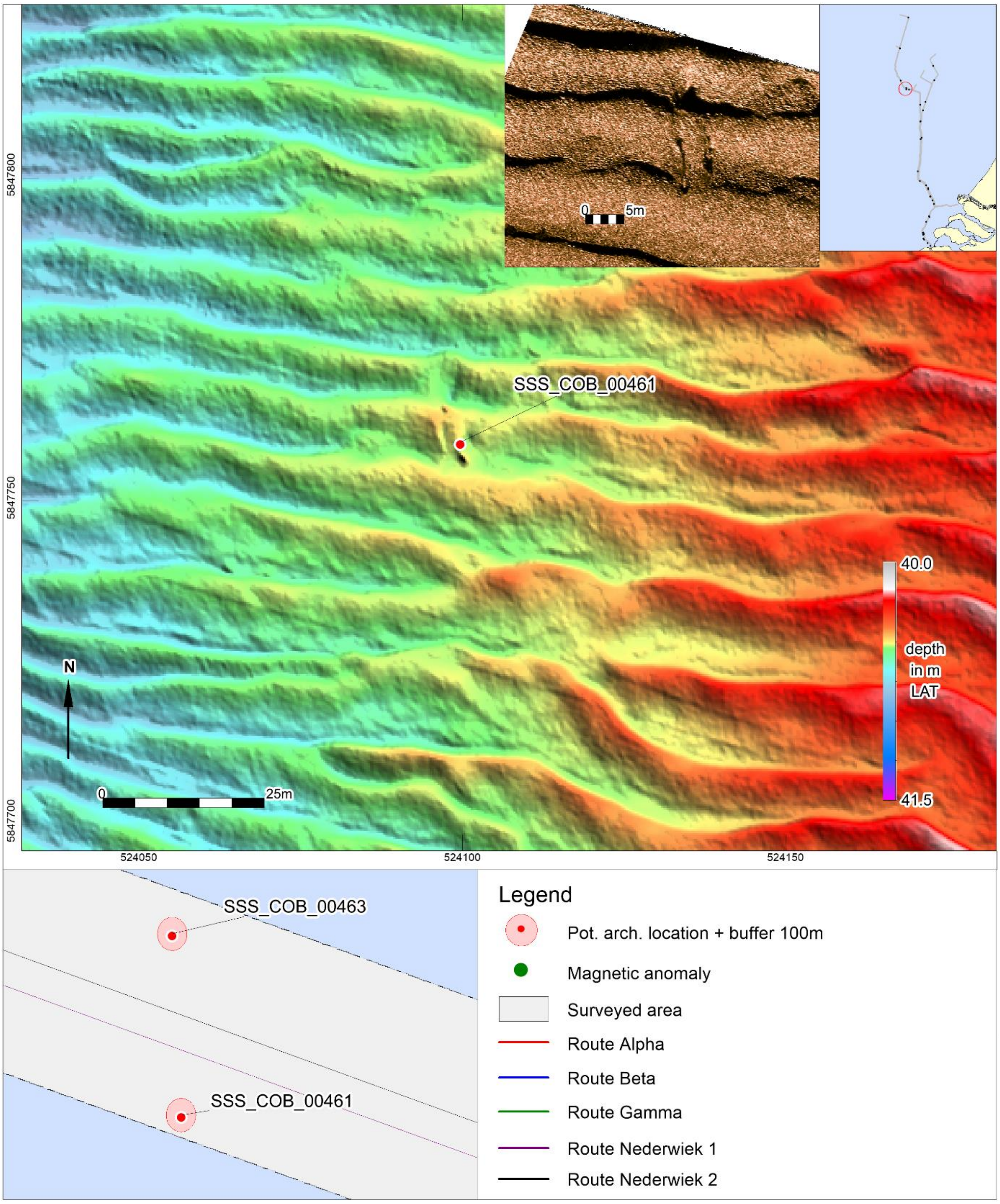
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
11020	Debris Other	4.7	0.9	0.3	542369	5764697	-28.5	36.427

NCN	Description PPA	Classification PPA	Class
-	Oval contact, 4.7 x 0.9 x 0.3. possible wreck remains	Possible wreck remains	1



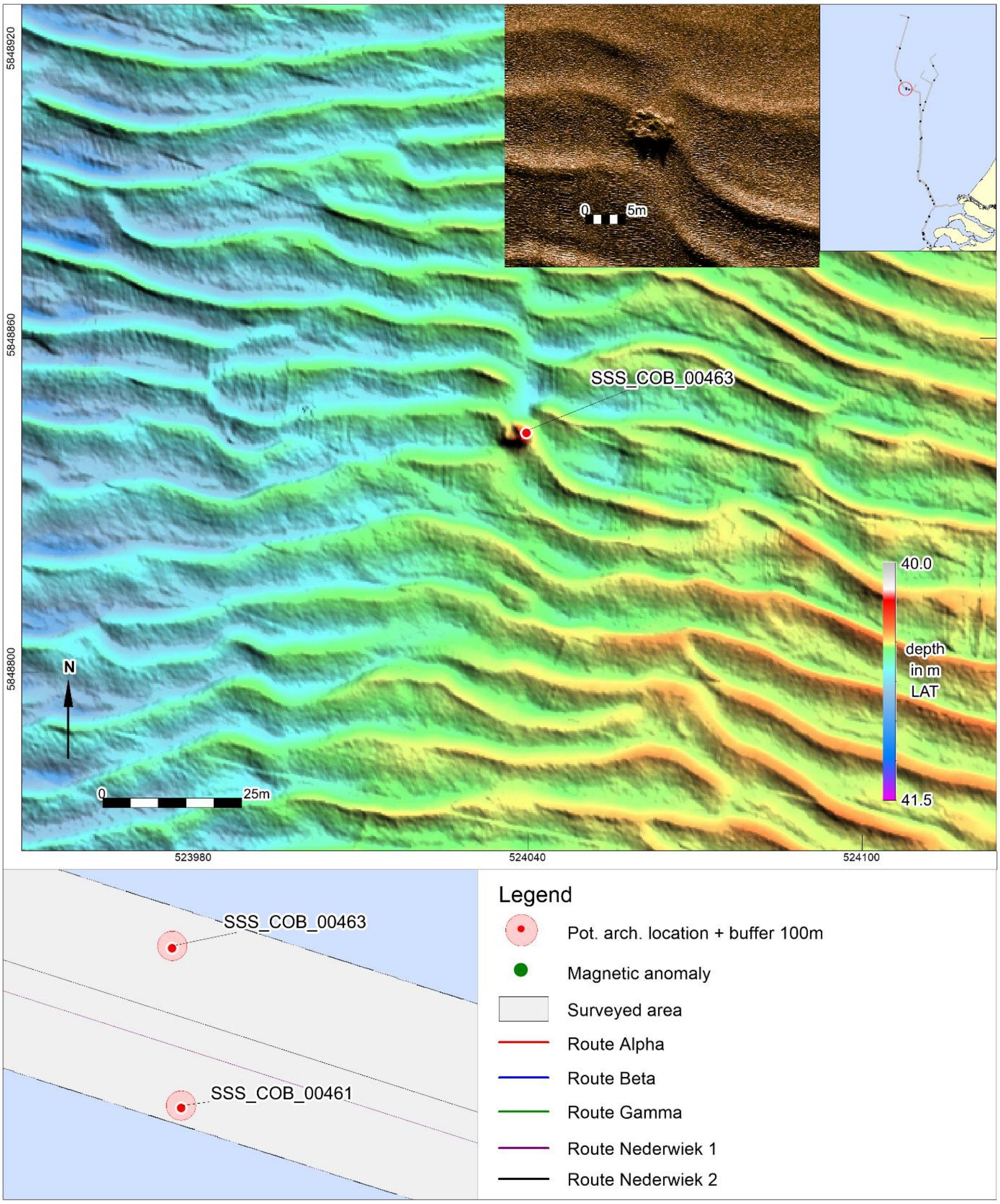
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
438	Debris Other	4.1	2.6	0.7	526488	5847207	-35.1	130.014

NCN	Description PPA	Classification PPA	Class
-	Oval contact, 4.1 x 2.6 x 0.7, which ‘breaks’ a sand wave.	Possible wreck remains	1



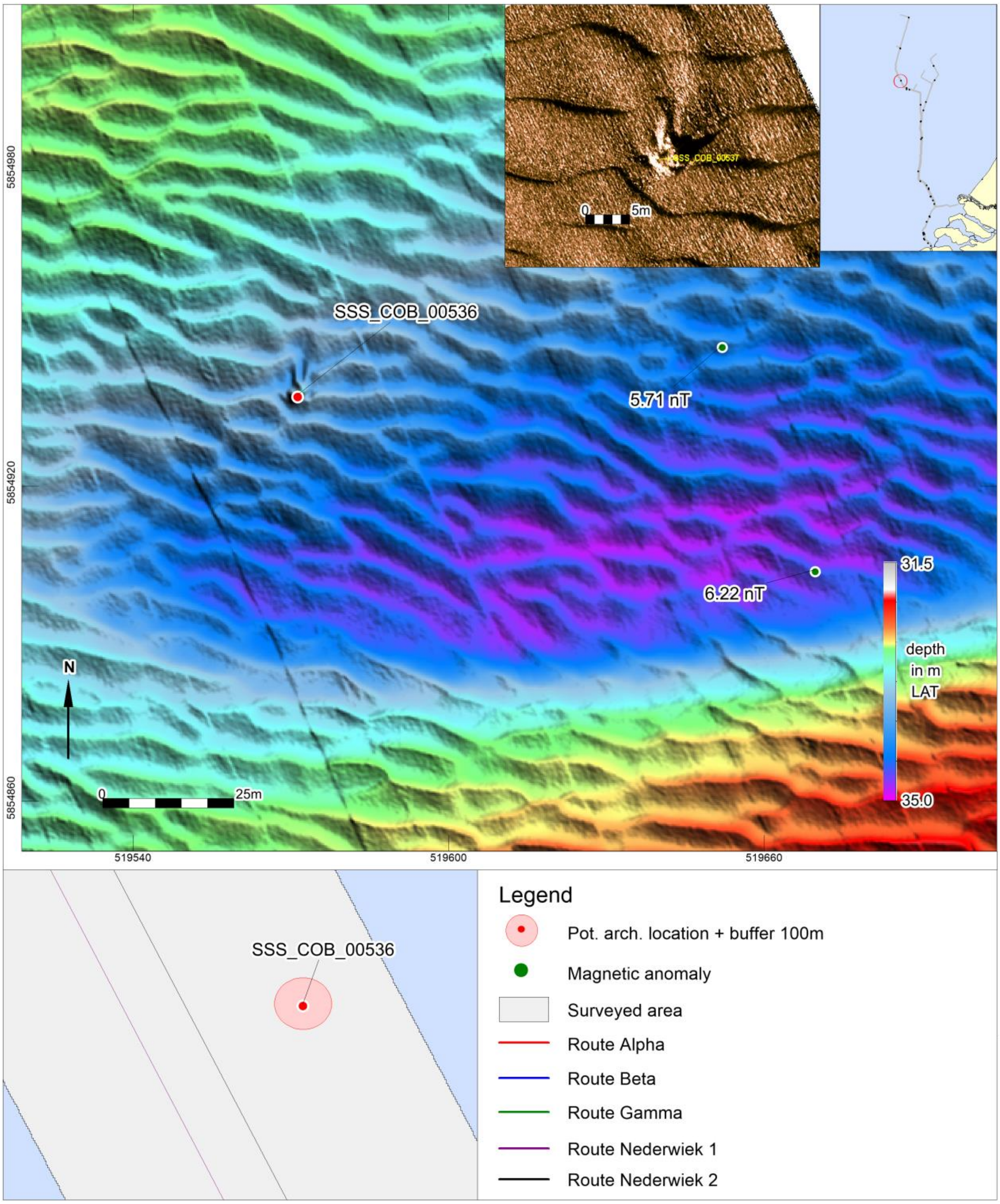
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
00461	Debris Linear	11.9	0.0	0.0	524100	5847759	-40.7	132.458

NCN	Description PPA	Classification PPA	Class
-	Oval contact, 12.5 x 3.8m possibly partially buried wreck	Possible wreck remains	1



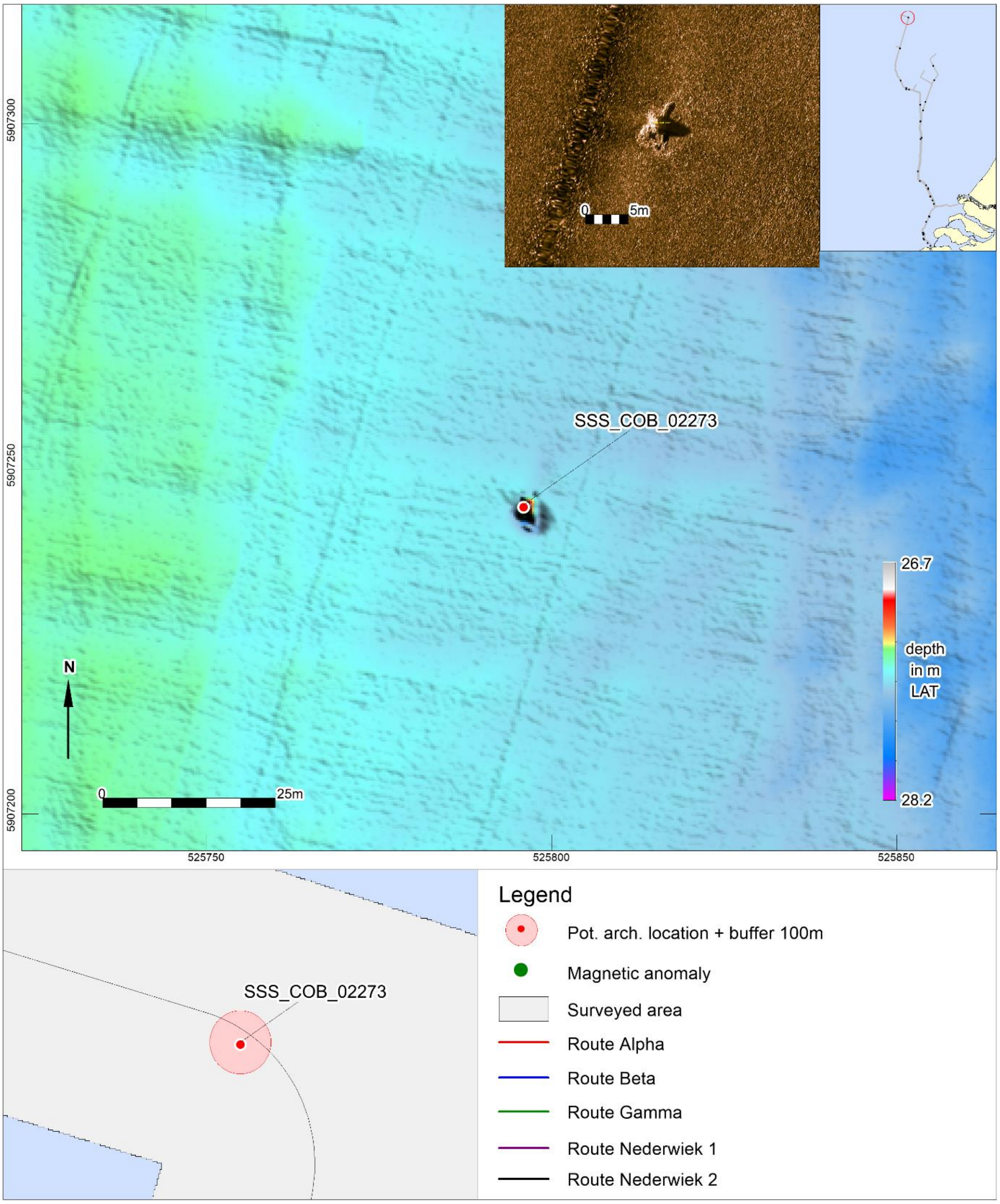
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
00463	Debris Other	6.1	3.5	0.8	524040	5848843	-40.5	132.846

NCN	Description PPA	Classification PPA	Class
-	Irregular shaped object, possible wreck remains	Possible wreck remains	1



ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
00536	Debris Other	6.2	3.6	0.8	519571	5854937	-34.0	141.204

NCN	Description PPA	Classification PPA	Class
-	Irregular shaped contact with a sharp shadow, possible wreck remains.	Possible wreck remains	1



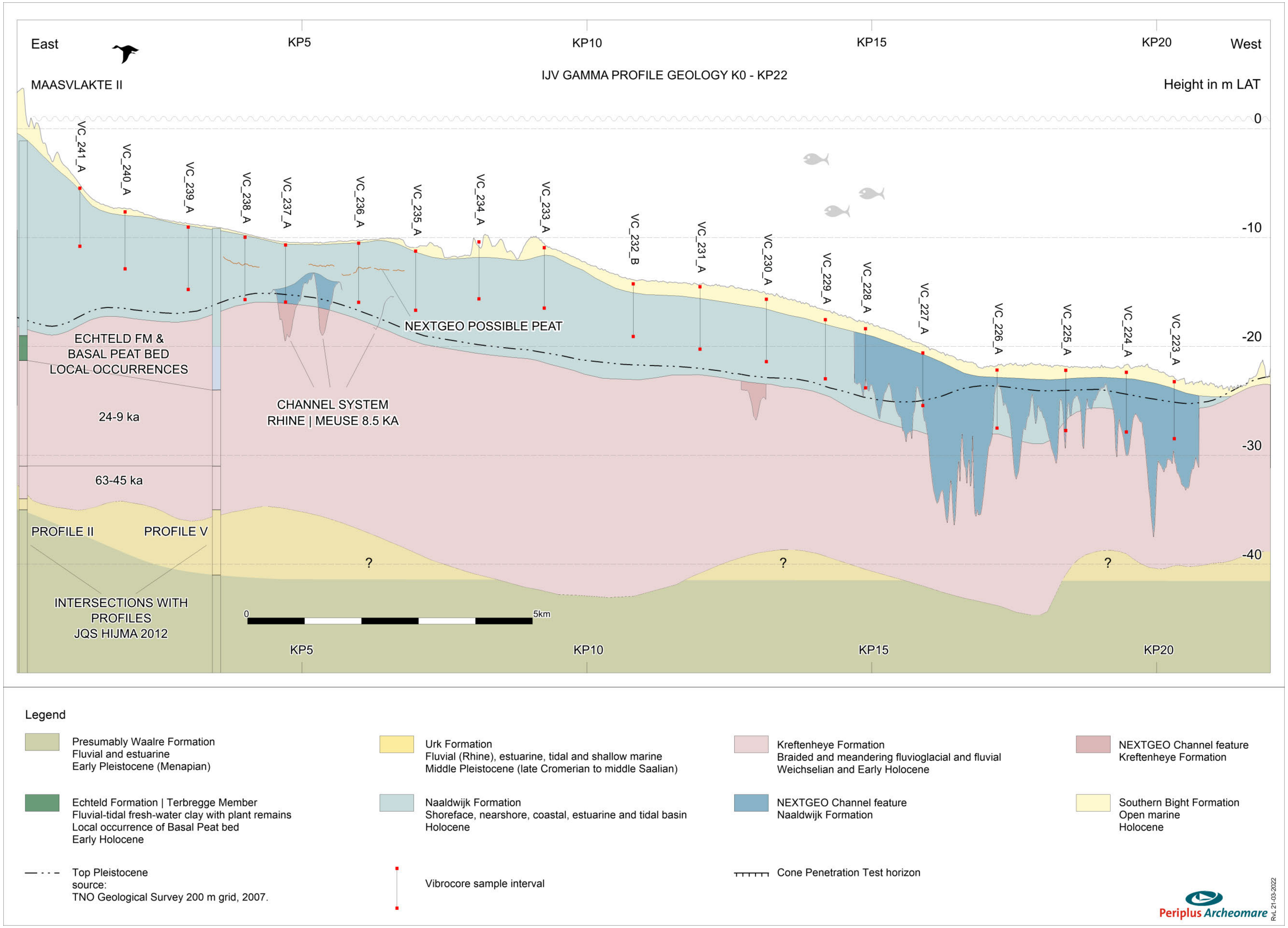
ID	Feature Next	Length	Width	Height	Easting	Northing	Depth	KP NW 2
02273	Debris Fish Net	1.4	1.8	5.5	525796	5907245	-27.8	196.79

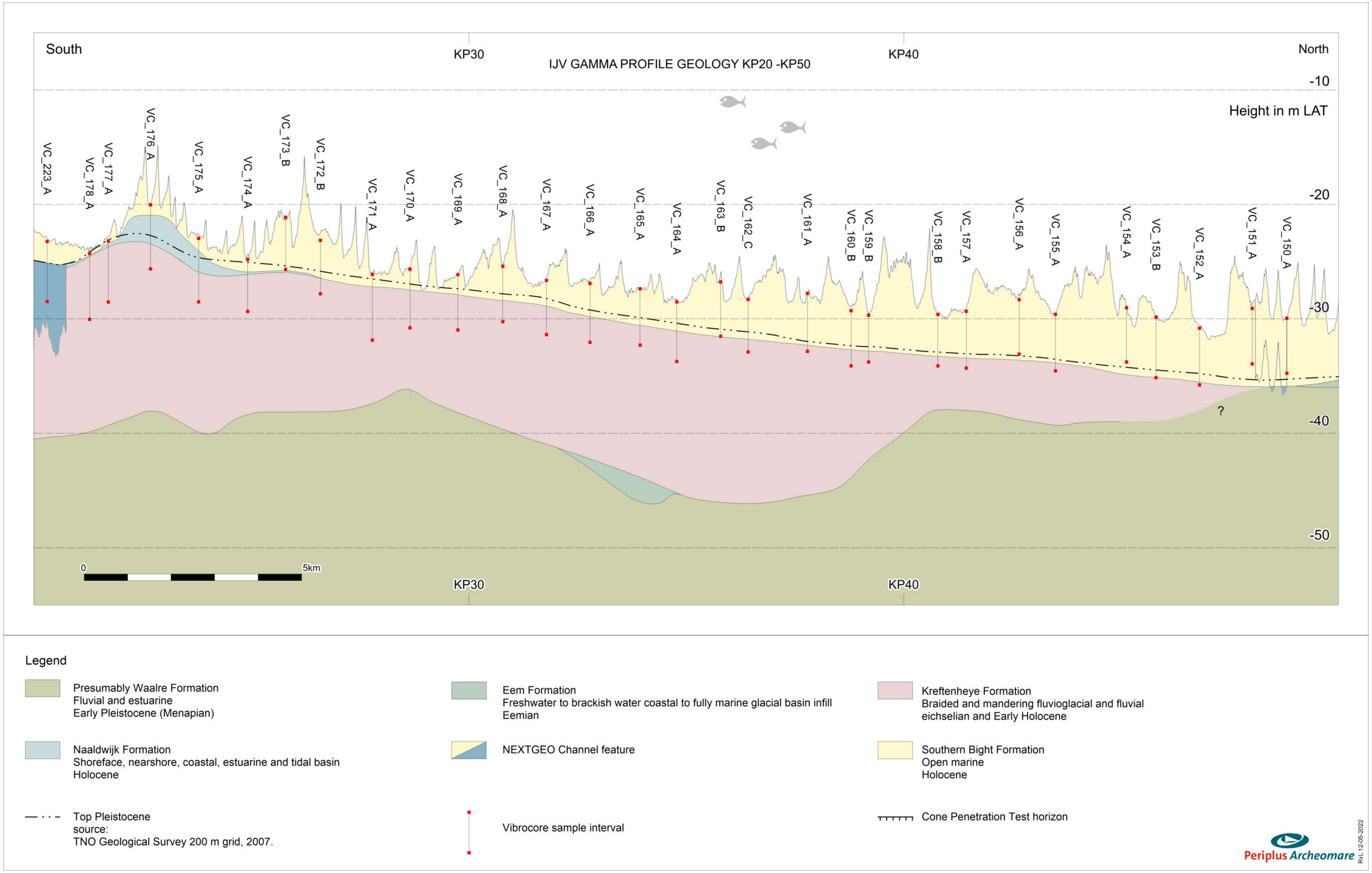
NCN	Description PPA	Classification PPA	Class
-	Irregular shaped contact, possible wreck remains.	Possible wreck remains	1

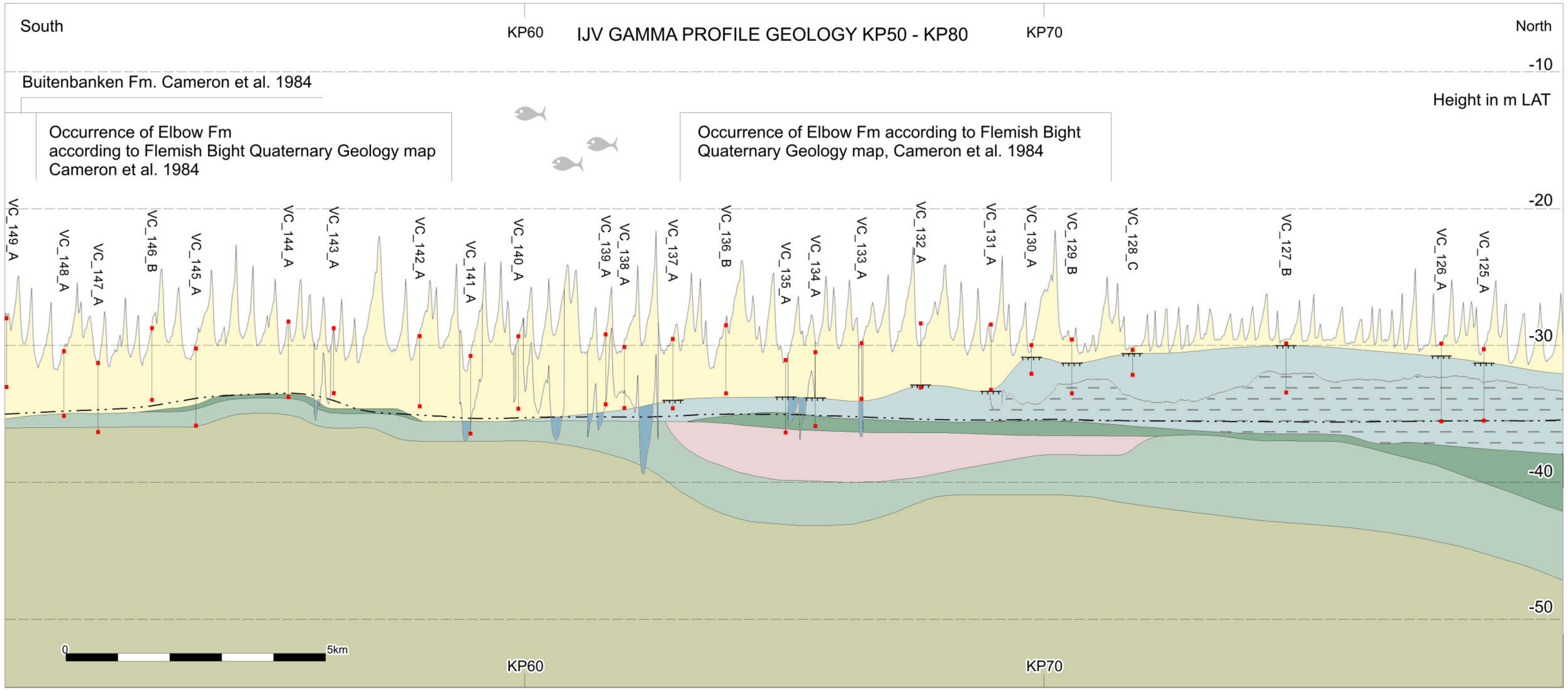
Appendix 2. Geological cross-sections along the Nederwiek 2 route trajectory

Note:
Apart from the last cross-section from KP 165.00 – KP 203.92 the included cross-sections have been obtained from:

- Periplus Archeomare Report 21A001-02 (v2.0), Appendix 2: 'Net op Zee IJmuiden Ver (Alpha) – An archaeological assessment of geophysical & geotechnical survey results.',
- Periplus Archeomare Report 21A002-06 (v2.0), Appendix 2: 'Net op Zee IJmuiden Ver (Gamma) – An archaeological assessment of geophysical & geotechnical survey results.', and
- Periplus Archeomare Report 22A027-02 (v1.0), Appendix 2: 'Net op Zee Nederwiek 1 – An archaeological assessment of geophysical & geotechnical survey results.'


East
KP5
KP10
KP15
KP20
West
MAASVLAKTE II
IJV GAMMA PROFILE GEOLOGY K0 - KP22
Height in m LAT
0
-10
-20
-30
-40
VC_241_A
VC_240_A
VC_239_A
VC_238_A
VC_237_A
VC_236_A
VC_235_A
VC_234_A
VC_233_A
VC_232_B
VC_231_A
VC_230_A
VC_229_A
VC_228_A
VC_227_A
VC_226_A
VC_225_A
VC_224_A
VC_223_A
NEXTGEO POSSIBLE PEAT
ECHTELD FM & BASAL PEAT BED LOCAL OCCURRENCES
24-9 ka
63-45 ka
CHANNEL SYSTEM RHINE | MEUSE 8.5 KA
PROFILE II
PROFILE V
INTERSECTIONS WITH PROFILES JQS HIJMA 2012
?
0
5km
Legend
Presumably Waalre Formation
Fluvial and estuarine
Early Pleistocene (Menapian)
Urk Formation
Fluvial (Rhine), estuarine, tidal and shallow marine
Middle Pleistocene (late Cromerian to middle Saalian)
Kreftenheye Formation
Braided and meandering fluvioglacial and fluvial
Weichselian and Early Holocene
NEXTGEO Channel feature
Kreftenheye Formation
Echteld Formation | Terbregge Member
Fluvial-tidal fresh-water clay with plant remains
Local occurrence of Basal Peat bed
Early Holocene
Naaldwijk Formation
Shoreface, nearshore, coastal, estuarine and tidal basin
Holocene
NEXTGEO Channel feature
Naaldwijk Formation
Southern Bight Formation
Open marine
Holocene
Top Pleistocene
source:
TNO Geological Survey 200 m grid, 2007.
Vibrocore sample interval
Cone Penetration Test horizon
Periplus Archeomare
Rvl. 21-03-2022


South
KP30
IJV GAMMA PROFILE GEOLOGY KP20 -KP50
KP40
North
-10
Height in m LAT
-20
-30
-40
-50
VC_223_A
VC_178_A
VC_177_A
VC_176_A
VC_175_A
VC_174_A
VC_173_B
VC_172_B
VC_171_A
VC_170_A
VC_169_A
VC_168_A
VC_167_A
VC_166_A
VC_165_A
VC_164_A
VC_163_B
VC_162_C
VC_161_A
VC_160_B
VC_159_B
VC_158_B
VC_157_A
VC_156_A
VC_155_A
VC_154_A
VC_153_B
VC_152_A
VC_151_A
VC_150_A
?
0
5km
KP30
KP40
Legend
Presumably Waalre Formation
Fluvial and estuarine
Early Pleistocene (Menapian)
Eem Formation
Freshwater to brackish water coastal to fully marine glacial basin infill
Eemian
Kreftenheye Formation
Braided and mandering fluvioglacial and fluvial
eichselian and Early Holocene
Naaldwijk Formation
Shoreface, nearshore, coastal, estuarine and tidal basin
Holocene
NEXTGEO Channel feature
Southern Bight Formation
Open marine
Holocene
Top Pleistocene
source:
TNO Geological Survey 200 m grid, 2007.
Vibrocore sample interval
Cone Penetration Test horizon
Periplus Archeomare
Rvt. 12-05-2022



Legend

- Southern Bight Formation
  Open marine
  Holocene
- GEOxyz Channel feature
- GEOxyz Layered Sediments
- Uncertain: Naaldwijk Fm | Boxtel Fm | Brown Bank Mb
  * Naaldwijk Formation
  Shoreface, nearshore, coastal, estuarine and tidal basin
  Holocene
  * Boxtel Formation
  Periglacial aeolian (coversand), lacustrine and small-scale fluvial
  Weichselian - Early Holocene
- Top Pleistocene
  source:
  TNO Geological Survey 200 m grid, 2007.
- Kreftenheye Formation
  Braided and meandering fluvioglacial and fluvial
  Weichselian and Early Holocene
- Eem Formation - Brown Bank Member
  Regressive brackish lagoonal to stream-fed lacustrine
  Early Weichselian
- Eem Formation
  Freshwater to brackish water coastal to fully marine glacial basin infill
  Eemian
- Yarmouth Roads Formation (offshore equivalent Waalre Formation)
  Fluvial and estuarine
  Early Pleistocene (Menapian)
- Vibrocore sample interval
- Cone Penetration Test horizon

NOTES:

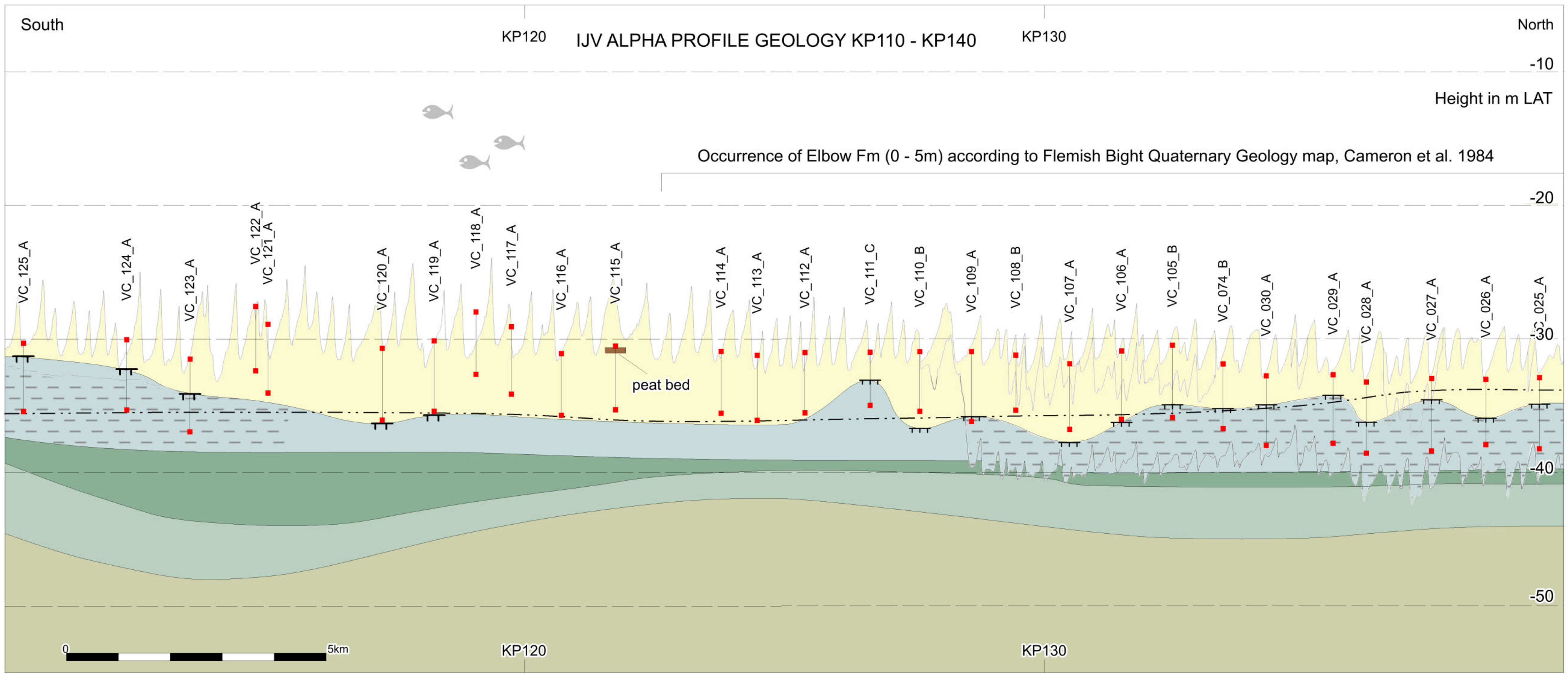
1)
The Pleistocene units in this profile are based on grid data of TNO (2004). The Kreftenheye Formation appears to separate the Eem Formation from the Brown Bank Member (Eem Formation). It is questioned if this is correct, because the Kreftenheye Formation is stratigraphically positioned above the Eem Formation and generally post-dates the Brown Bank Member.

2)
The Buitenbanken Formation and the Elbow Formation are Holocene units mapped on the 1984 'Flemish Bight' geological maps produced by Cameron, Laban and Schuttenhelm. The names are outdated and no longer used. The Elbow Formation is defined as a mostly 2 - 6 m thick unit, which consists of fine- or very fine-grained blueish-grey muddy sands with interbedded clay. A basal early Boreal peat bed with intercallations of wind-blown or fluvial sand is up to 1 m thick and locatlly present in the Dutch sector. The Buitenbanken Formation is mostly less than 2 m thick and commonly consists of medium-grained sands with reworked Eemian or Early Pleistocene sands. The Elbow Formation shall in accordancence with the current nomenclature be classified as the Wormer Member within the Naaldwijk Formation with locally at its base the Basal Peat bed and/or Velsen Bed. The Buitenbanken Member is now classified as the Naaldwijk Formation.

3)
The TNO 2004 grid do not include the Elbow Formation. Grid data of the Buitenbanken Member are available but do not coincided with occurrences on the 1984 Flemish Bight map.

Periplus Archeomare

Rvl. 12-05-2022



Legend

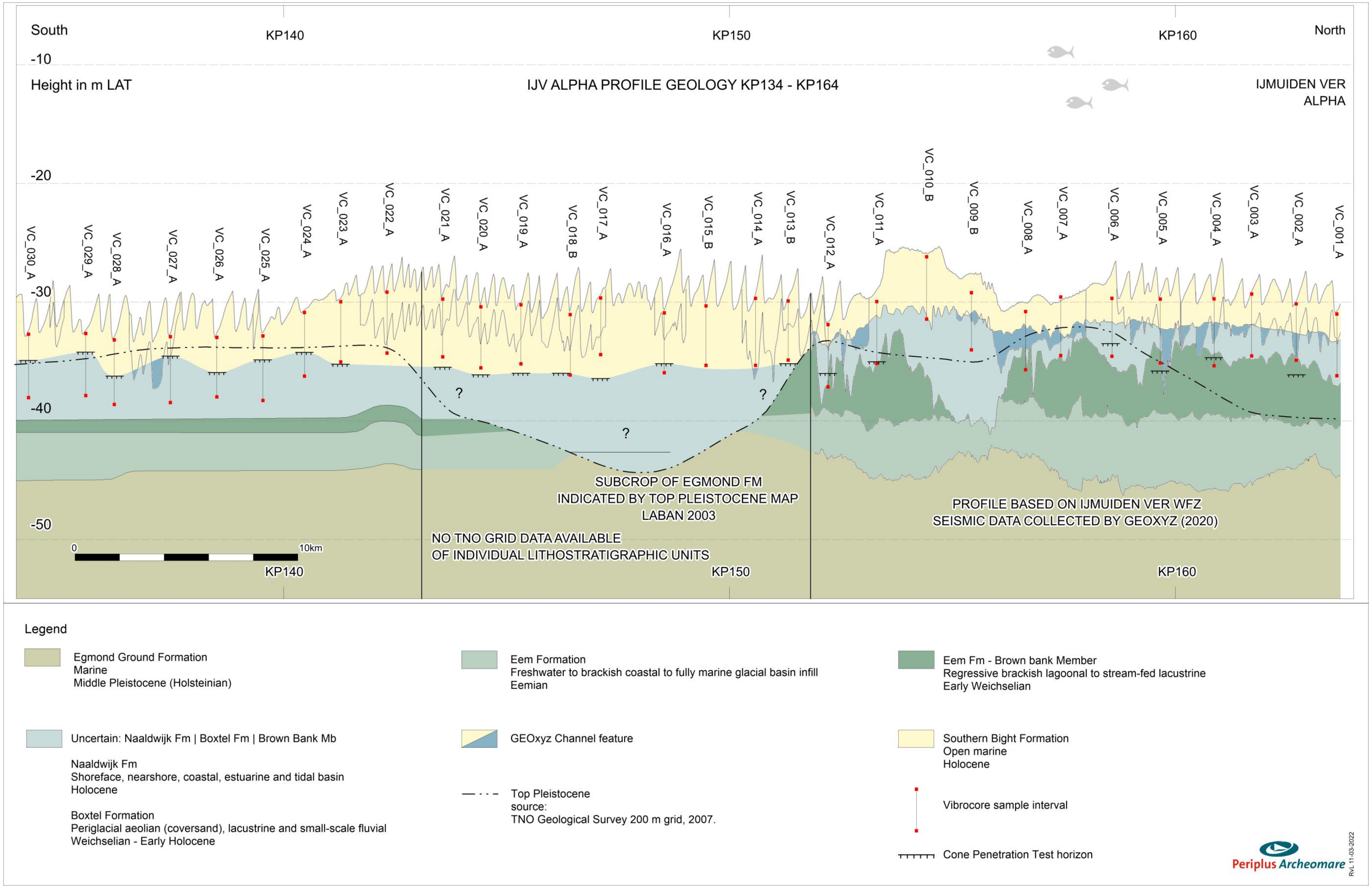
- Southern Bight Formation
  Open marine
  Holocene
- NEXTGEO Channel feature
- NEXTGEO Layered Sediments
- Uncertain: Naaldwijk Fm | Boxtel Fm | Brown Bank Mb
  * Naaldwijk Formation
  Shoreface, nearshore, coastal, estuarine and tidal basin
  Holocene
  * Boxtel Formation
  Periglacial aeolian (coversand), lacustrine and small-scale fluvial
  Weichselian - Early Holocene
- Top Pleistocene
  source:
  TNO Geological Survey 200 m grid, 2007.
- Eem Formation - Brown Bank Member
  Regressive brackish lagoonal to stream-fed lacustrine
  Early Weichselian
- Eem Formation
  Freshwater to brackish water coastal to fully marine glacial basin infill
  Eemian
- Yarmouth Roads Formation (offshore equivalent Waalre Formation)
  Fluvial and estuarine
  Early Pleistocene (Menapian)
- Vibrocore sample interval
- Cone Penetration Test horizon

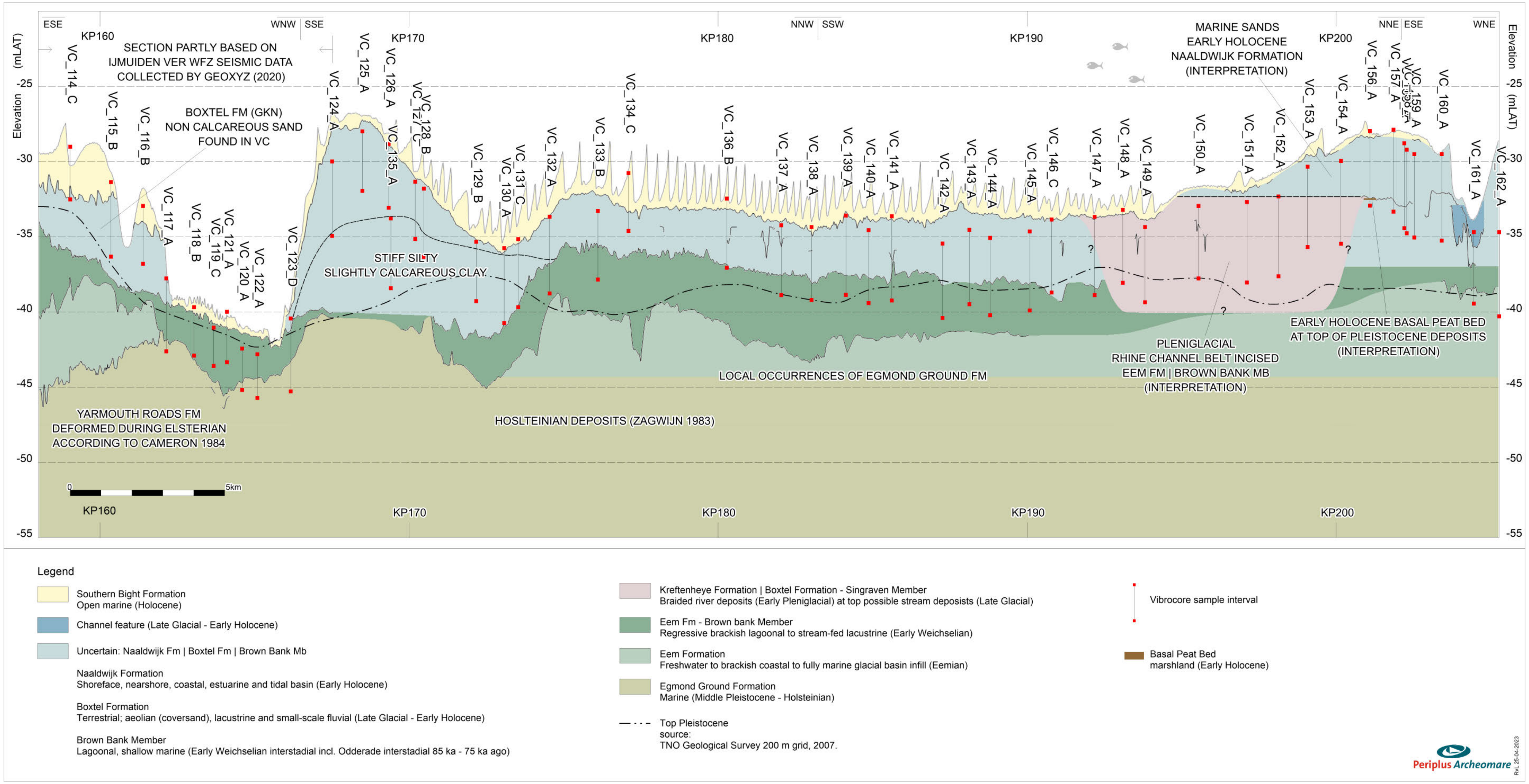
NOTES:

1)
The Buitenbanken Formation and the Elbow Formation are Holocene units mapped on the 1984 'Flemish Bight' geological maps produced by Cameron, Laban and Schuttenhelm. The names are outdated and no longer used. The Elbow Formation is defined as a mostly 2 - 6 m thick unit, which consists of fine- or very fine-grained blueish-grey muddy sands with interbedded clay. A basal early Boreal peat bed with intercallations of wind-blown or fluvial sand is up to 1 m thick and locatlly present in the Dutch sector. The Buitenbanken Formation is mostly less than 2 m thick and commonly consists of medium-grained sands with reworked Eemian or Early Pleistocene sands. The Elbow Formation shall in accordance with the current nomenclature be classified as the Wormer Member within the Naaldwijk Formation with locally at its base the Basal Peat bed and/or Velsen Bed. The Buitenbanken Member is now classified as the Naaldwijk Formation.

2)
The TNO 2004 grid do not include the Elbow Formation. Grid data of the Buitenbanken Member are available but do not coincided with occurrences on the 1984 Flemish Bight map.

Periplus Archeomare
Rvl. 29-03-2022


South
KP140
KP150
KP160
North
-10
Height in m LAT
IJV ALPHA PROFILE GEOLOGY KP134 - KP164
IJMUIDEN VER ALPHA
-20
-30
-40
-50
VC_030_A
VC_029_A
VC_028_A
VC_027_A
VC_026_A
VC_025_A
VC_024_A
VC_023_A
VC_022_A
VC_021_A
VC_020_A
VC_019_A
VC_018_B
VC_017_A
VC_016_A
VC_015_B
VC_014_A
VC_013_B
VC_012_A
VC_011_A
VC_010_B
VC_009_B
VC_008_A
VC_007_A
VC_006_A
VC_005_A
VC_004_A
VC_003_A
VC_002_A
VC_001_A
?
SUBCROP OF EGMOND FM
INDICATED BY TOP PLEISTOCENE MAP
LABAN 2003
PROFILE BASED ON IJMUIDEN VER WFZ
SEISMIC DATA COLLECTED BY GEOXYZ (2020)
0
10km
NO TNO GRID DATA AVAILABLE
OF INDIVIDUAL LITHOSTRATIGRAPHIC UNITS
Legend
Egmond Ground Formation
Marine
Middle Pleistocene (Holsteinian)
Eem Formation
Freshwater to brackish coastal to fully marine glacial basin infill
Eemian
Eem Fm - Brown bank Member
Regressive brackish lagoonal to stream-fed lacustrine
Early Weichselian
Uncertain: Naaldwijk Fm | Boxtel Fm | Brown Bank Mb
Naaldwijk Fm
Shoreface, nearshore, coastal, estuarine and tidal basin
Holocene
Boxtel Formation
Periglacial aeolian (coversand), lacustrine and small-scale fluvial
Weichselian - Early Holocene
GEOxyz Channel feature
Top Pleistocene
source:
TNO Geological Survey 200 m grid, 2007.
Southern Bight Formation
Open marine
Holocene
Vibrocore sample interval
Cone Penetration Test horizon
Periplus Archeomare
RvL 11-03-2022


ESE
WNW | SSE
NNW | SSW
NNE | ESE
WNE
KP160
KP170
KP180
KP190
KP200
Elevation (mLAT)
SECTION PARTLY BASED ON IJMUIDEN VER WFZ SEISMIC DATA COLLECTED BY GEOXYZ (2020)
BOXTEL FM (GKN) NON CALCAREOUS SAND FOUND IN VC
STIFF SILTY SLIGHTLY CALCAREOUS CLAY
MARINE SANDS EARLY HOLOCENE NAALDWIJK FORMATION (INTERPRETATION)
EARLY HOLOCENE BASAL PEAT BED AT TOP OF PLEISTOCENE DEPOSITS (INTERPRETATION)
PLENIGLACIAL RHINE CHANNEL BELT INCISED EEM FM | BROWN BANK MB (INTERPRETATION)
LOCAL OCCURRENCES OF EGMOND GROUND FM
YARMOUTH ROADS FM DEFORMED DURING ELSTERIAN ACCORDING TO CAMERON 1984
HOSLTEINIAN DEPOSITS (ZAGWIJN 1983)
0
5km
-25
-30
-35
-40
-45
-50
-55
Legend
Southern Bight Formation
Open marine (Holocene)
Channel feature (Late Glacial - Early Holocene)
Uncertain: Naaldwijk Fm | Boxtel Fm | Brown Bank Mb
Naaldwijk Formation
Shoreface, nearshore, coastal, estuarine and tidal basin (Early Holocene)
Boxtel Formation
Terrestrial: aeolian (coversand), lacustrine and small-scale fluvial (Late Glacial - Early Holocene)
Brown Bank Member
Lagoonal, shallow marine (Early Weichselian interstadial incl. Odderade interstadial 85 ka - 75 ka ago)
Kreftenheye Formation | Boxtel Formation - Singraven Member
Braided river deposits (Early Pleniglacial) at top possible stream deposists (Late Glacial)
Eem Fm - Brown bank Member
Regressive brackish lagoonal to stream-fed lacustrine (Early Weichselian)
Eem Formation
Freshwater to brackish coastal to fully marine glacial basin infill (Eemian)
Egmond Ground Formation
Marine (Middle Pleistocene - Holsteinian)
Top Pleistocene
source:
TNO Geological Survey 200 m grid, 2007.
Vibrocore sample interval
Basal Peat Bed
marshland (Early Holocene)
Periplus Archeomare

Appendix 3. Geological and archaeological timetable

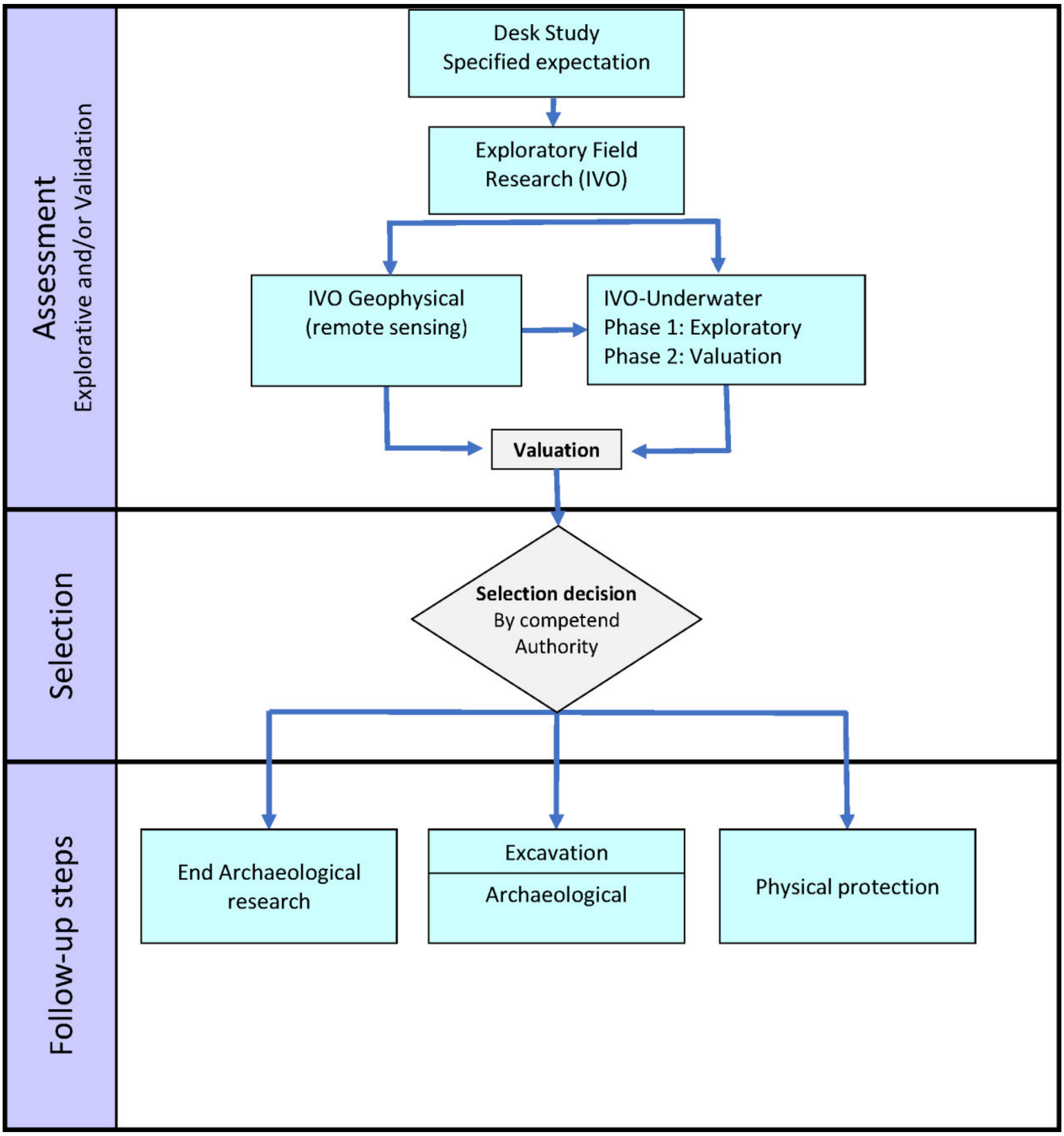
CHRONOSTRATIGRAFIE

SERIE	ETAGE - CHRONOZONE			TIJD
Holoceen	**Laat Subatlanticum**			**1150 n. Chr**
Holoceen	Vroeg Subatlanticum			0
				450 v. Chr
Holoceen	Subboreaal			3700
Holoceen	Atlanticum			7300
Holoceen	Boreaal			8700
Holoceen	Preboreaal			9700
Pleistoceen	Weichselien	Laat Glaciaal	Jonge Dryas	11.000
Pleistoceen	Weichselien	Laat Glaciaal	Allerød	12.000
Pleistoceen	Weichselien	Laat Glaciaal	Oude Dryas	12.100
Pleistoceen	Weichselien	Laat Glaciaal	Bølling	13.000
Pleistoceen	Weichselien	Pleniglaciaal L		17.000
Pleistoceen	Weichselien	Pleniglaciaal L	Late Glacial Max	20.000
Pleistoceen	Weichselien	Pleniglaciaal L		31.500
Pleistoceen	Weichselien	Pleniglaciaal L	Denekamp	34.000
Pleistoceen	Weichselien	Pleniglaciaal M		40.000
Pleistoceen	Weichselien	Pleniglaciaal M	Hengelo	41.500
Pleistoceen	Weichselien	Pleniglaciaal M		45.000
Pleistoceen	Weichselien	Pleniglaciaal V	Moershoofd	50.000
Pleistoceen	Weichselien	Pleniglaciaal V		71.000
Pleistoceen	Weichselien	Vroeg Glaciaal	Odderade	74.000
Pleistoceen	Weichselien	Vroeg Glaciaal		
Pleistoceen	Weichselien	Vroeg Glaciaal	Brørup	
Pleistoceen	Weichselien	Vroeg Glaciaal		
Pleistoceen	Weichselien	Vroeg Glaciaal	Amersfoort	
Pleistoceen	Weichselien	Vroeg Glaciaal		114.000
Pleistoceen	Eemien			126.000
Pleistoceen	Saalien			236.000
Pleistoceen	Oostermeer			241.000
Pleistoceen	onbenoemd			322.000
Pleistoceen	Belvédère			336.000
Pleistoceen	onbenoemd			384.000
Pleistoceen	Holsteinien			416.000
Pleistoceen	Elsterien			463.000

ARCHEOLOGISCHE PERIODE

TIJDPERK				DATERING
		Nieuwe tijd	C	1850
		Nieuwe tijd	B	1650
		Nieuwe tijd	A	1500
		Middeleeuwen	Laat B	1250
		Middeleeuwen	Laat A	1050
		Middeleeuwen	Vroeg D	900
		Middeleeuwen	Vroeg C	725
		Middeleeuwen	Vroeg B	525
		Middeleeuwen	Vroeg A	450
		Romeinse tijd	Laat	270
		Romeinse tijd	Midden	70 n. Chr.
		Romeinse tijd	Vroeg	15 v. Chr.
Prehistorie	Metaaltijden	IJzertijd	Laat	250
Prehistorie	Metaaltijden	IJzertijd	Midden	500
Prehistorie	Metaaltijden	IJzertijd	Vroeg	800
Prehistorie	Metaaltijden	Bronstijd	Laat	1100
Prehistorie	Metaaltijden	Bronstijd	Midden	1800
Prehistorie	Metaaltijden	Bronstijd	Vroeg	2000
Prehistorie	Steentijd	Neolithicum	Laat	2850
Prehistorie	Steentijd	Neolithicum	Midden	4200
Prehistorie	Steentijd	Neolithicum	Vroeg	4900/5300
Prehistorie	Steentijd	Mesolithicum	Laat	6450
Prehistorie	Steentijd	Mesolithicum	Midden	8640
Prehistorie	Steentijd	Mesolithicum	Vroeg	9700
Prehistorie	Steentijd	Paleolithicum	Laat B	12.500
Prehistorie	Steentijd	Paleolithicum	Jong B	16.000
Prehistorie	Steentijd	Paleolithicum	Jong A	35.000
Prehistorie	Steentijd	Paleolithicum	Midden	250.000
Prehistorie	Steentijd	Paleolithicum	Oud	

Appendix 4. Schematic overview KNA Waterbodems version 4.1



Appendix 5. Geophysical and geotechnical survey report

- NextGEO, 2023. OFFSHORE GRID NL - Offshore Route Survey Activities (non-UXO) Nederwiek 1,2 and 3. Final Report - Integrated Geophysical & Geotechnical Report.